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THE EVALUATION OF MICROBIOLOGICAL AEROSOLS ASSOCIATED WITH THE APPLICATION OF WASTEWATER TO LAND: PLEASANTON, CALIFORNIA

FINAL REPORT

June 1979

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The purpose was to determine extent that individuals near spray irrigation sites are exposed to microorganisms in wastewater aerosols. Report covers Phase II -- a monitoring effort from May 1976 to April 1977 of a spray irrigation site utilizing unchlorinated secondarily-treated wastewater from biofiltration treatment process. Objectives included an in-depth pathogen screen of wastewater, establishing the relationship between pathogen levels and traditional indicator organisms, monitoring microorganisms in air within 600 meters

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of the spray source, and development/validation of a microbiological dispersion model for predicting pathogen aerosol concentrations. Effluent was monitored for microbiological, chemical, and physical characteristics; extensive microorganism and dye aerosol samples were collected (77 aerosol runs). Enteroviruses were detected in air, but at a very low concentration. Conclusions: There is considerable underestimation of pathogen aerosol levels when using traditional indicators to predict human exposures to enteroviruses. Microbiological dispersion model may be used with minimal monitoring to estimate exposure. There is little correlation between wastewater levels of traditional indicators and pathogens. Microbiological wastewater aerosols are generated by spray irrigation, do survive aerosolization and can be transported to nearby populations. Until dose-response relationships are developed, neither levels of aerosolized microorganisms that constitute a hazard nor the degree of required wastewater disinfection can be specified.

EXECUTIVE SUMMARY

Application to land is perhaps the oldest method of disposing of wastewater, and an attractive modern alternative. The advantages include re-use of the water, avoiding contamination of bodies of surface water, and return of nutrients in the wastewater to the soil. The most frequent means of application is spray irrigation, which can be applied to a wide variety of land sites where the topography of the land would make other methods of irrigation infeasible.

Aerosols containing pathogenic microorganisms are created during wastewater spraying and the organisms can be transported to populated areas by prevailing winds. The principal purposes of this program were to determine to what extent individuals living near sites practicing spray irrigation are exposed to these microorganisms and to gain insight into the potential health effects. Gastro-intestinal and respiratory illnesses such as dysentery, typhoid fever, and infectious hepatitis might be spread by spraying poorly-treated, undisinfected wastewater.

The study was conducted at a spray irrigation site associated with a sewage treatment plant located in Pleasanton, California. Here, treatment plant effluent was utilized to irrigate grazing lands. The wastewater is secondarily treated but not chlorinated by a process called contact biofiltration, and approximately 1.4 million gallons per day are sprayed onto the fields. The program was designed with three potential phases, Phase I was to be a site characterization, Phase II to be extensive aerosol monitoring effort, and Phase III an epidemiology study of the exposed population. This report covers the Phase II monitoring effort, which was conducted over the period from May 1976 to April 1977.

There were two distinct efforts performed in Phase II. The sewage treatment plant receives a large input from the Alameda County Fair during a month-long period each summer and the sewage effluent at this time is not typical of the remainder of the year. The decision was made not to monitor during this period, but to monitor both before and after the fair. The two efforts were conducted with differing sets of objectives, and these were designated as Pre-Fair and Post-Fair.

The principal objectives of the Pre-Fair study were to perform an in-depth pathogen screen of the wastewater, to establish the relationship in wastewater between pathogen levels and levels of the traditional indicator organisms (total and fecal coliform and standard bacterial plate count), to determine microorganism levels in air within 100 meters of the spray source, and to begin the assessment of factors thought to affect the levels of pathogenic organisms collected in aerosol samples, including aerosolization efficiency, pathogen survival upon becoming airborne (impact), and microbiological die-off with time (viability decay). These factors were to be used to begin development of a predictive model of pathogen concentration to estimate the degree of exposure of the nearby populations.

The objectives of the Post-Fair study were primarily oriented toward the development and validation of a predictive model. To accomplish this goal, air sampling was to be conducted to 600 meters downwind, the factors affecting microbiological aerosols were to be identified and quantified over a wide range of meteorological conditions, and sufficient aerosol runs were to be completed to permit model development. The model developed from the Pre-Fair and Post-Fair data was then to be validated using data from studies at Fort Huachuca and Deer Creek and some Pleasanton data not usable in model development.

To accomplish these objectives, it was necessary to monitor the effluent for its chemical and physical characteristics as well as microbiological constituents and to obtain large volumes of the wastewater for pathogen screening. Extensive aerosol samples were to be collected downwind and upwind of the spray line to determine the concentration of both traditional microorganism groups and of pathogens, and to compare these concentrations with the expected levels based on the spray rate and the microorganism levels in the effluent. Additionally, samples were taken after the injection of dye into the wastewater to allow estimation of the proportion of the sprayed effluent that became aerosolized.

Routine monitoring of the wastewater for chemical, physical, and microbiological parameters was accomplished during Pre-Fair by taking a composite sample from the aeration basin during the hours of spraying. Chemical and physical analyses included total and free chlorine, pH, total organic carbon (TOC), total solids, and total suspended solids (TSS). In addition, one-half of the composite samples were tested for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total phosphorus, hardness, and the nitrogen series, (nitrite, nitrate, ammonia, and organic nitrogen). Microbiological analyses run on all wastewater samples included total and fecal coliform, standard bacterial plate count, coliphage, and assays for selected pathogens, (*Klebsiella, Pseudomonas,* fecal streptococci, *Clostridium perfringens,* and 3- and 5-day enteroviruses).

To perform the wastewater pathogen screen, eight large-volume (20L) samples of effluent were taken at intervals throughout the Pre-Fair period and at the beginning of the Post-Fair period. These were sent to the UTSA-CART laboratory in San Antonio for a semi-quantitative screen to determine those microorganisms appearing with frequency in the effluent and to assist in selection of organisms for routine assay of wastewater and aerosol samples.

In the Post-Fair study routine chemical/physical analyses of the wastewater included pH, TOC, TSS and conductivity. Three samples were collected over the Post-Fair period for more detailed analyses, which included BOD, COD, total phosphorus, and the nitrogen series. Microbiological analyses conducted on all wastewater and aerosol samples included total coliform, coliphage, standard bacterial plate count, and selected pathogens. The pathogens sought in the Post-Fair period were limited to fecal streptococci and mycobacteria. The wastewater analyses were conducted on a composite sample taken in conjunction with each microbiological aerosol run.

Microbiological aerosol monitoring during both the Pre- and Post-Fair studies for microbiological aerosols was conducted using large-volume (1000 l/min) = 1 m^3/min) electrostatic precipitator samplers. These samplers were selected because the large volume of air sampled over a 30-minute period increases the sensitivity for the microbiological assay. Twenty-one successful aerosol runs were made during the Pre-Fair study and an additional 29 in the Post-Fair study. The collection and transfer medium selected was brain-heart infusion broth with 0.1 percent Tween 80®, which was shown to be adequate for sample concentration and for preservation of the microorganisms. The samples were analyzed for the same microbiological parameters as the wastewater, with the exception of one run for which the collecting fluids from all samplers were pooled for conduct of a pathogen screen.

A minimum of eight samplers was specified for each run and these were deployed along predesignated configurations to obtain the necessary information to perform the mathematical modeling. The distances of the samplers from the spray line were selected based upon sampling protocols and prevailing meteorological conditions. One sampler was used at a remote, upwind location to ascertain background concentrations of the organisms sought.

All-glass impingers were used to collect the aerosols from the dye runs, to determine the wastewater aerosolization efficiency of the sprinklers. Seven dye aerosol runs were conducted in Pre-Fair and an additional ten in Post-Fair.

In the Pre-Fair study, it was determined that virus levels in air consistently fell below the detection limit of the method and that special procedures would be required to obtain the necessary sensitivity. Two special virus runs were conducted in the Post-Fair study which increased the sensitivity and allowed estimation of impact factors for the enteroviruses. These two runs were conducted with all available samplers operating close to the spray line under meteorological conditions expected to result in high virus aerosol concentrations. The sampler collection medium was changed every 30 minutes and the samplers run for a total of about three hours. The collecting fluids were pooled and concentrated for analysis so that the results were based upon a total of over 5000 m^3 of air.

An explicit model for predicting downwind concentrations of pathogens was developed by expanding more general mathematical dispersion models. The model adds factors for microorganism impact, viability decay, and aerosolization efficiency, to the standard diffusion model estimate of pathogen concentration based of source strength. The distributions of aerosolization efficiency and the impact and decay values for each organism were determined and these were used to allow evaluation of the model using monitoring data from other sites.

The study was supported by an extensive quality assurance program conducted primarily during the Pre-Fair portion of Phase II. Chemical, physical, and microbiological methods used were subjected to accuracy and precision studies, and alternative laboratories were used, where feasible, to verify the results. Certain aerosol runs were made in both Pre- and Post-Fair to allow the determination of the precision of the microbiological assay procedures and the estimation of any sampler collection efficiency bias.

The Phase II study yielded several important conclusions. From the wastewater monitoring, the conclusion was reached that wastewater quality as measured by chemical and physical parameters was unrelated to the generation or transport of microbiological aerosols. In addition, little correlation could be found in the wastewater between levels of total coliform, fecal coliform, standard bacterial plate count, and coliphage (the traditional indicator organisms), with the levels of the pathogens which they are intended to indicate.

Results obtained from the aerosol studies indicate that use of the traditional indicator organisms to predict human population exposure results in extreme underestimation of pathogen levels. The pathogens studied survived the wastewater aerosolization process much better than did the indicator organisms. Based upon the results of this study, fecal streptococci may be an appropriate indicator due to ease of assay, levels routinely seen in wastewater, and the similarity of their hardiness upon impact and viability decay rate to those of the pathogenic organisms of interest.

Large-volume samplers of the type used in this study are most useful for obtaining the sensitivity required for assay for bacteria in aerosol samples, especially at background and far downwind locations. Sampling and analyses for enteroviruses in wastewater aerosols requires even greater volumes of air and only a special effort such as that performed here can be expected to provide the necessary sensitivity to allow their detection.

The dispersion model developed in this study was validated. It was shown to produce satisfactory results when used to predict aerosol concentrations at three sites. Most of the predicted results fell within a factor of five of the measured concentrations when non-chlorinated effluent was being sprayed. The use of such a model with minimal monitoring is a viable alternative to extensive aerosol monitoring, and is significantly less costly.

The overall conclusion of Phase II of this program is that microbiological wastewater aerosols are generated by spray irrigation, do survive aerosolization, and can be transported to nearby populations. The most reliable means of reducing a potential health hazard from pathogenic aerosols is by disinfecting the wastewater before spraying. Until the necessary dose-response relationships are developed, neither the level of aerosolized microorganisms that constitute a hazard nor the degree of required disinfection can be specified.

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I. SUMMARY AND CONCLUSIONS

A. Wastewater

1. Throughout the Pre-Fair and Post-Fair portions of this study there were no abrupt changes in wastewater quality which appeared to have an adverse effect on the results of the study. In general, the wastewater effluent applied was of relatively consistent day-to-day quality. No significant changes were observed during the conduct of a single aerosol run.

2. In general the quality of the irrigated wastewater was typical of an undisinfected, secondarily treated domestic wastewater. Mean values during the Pre-Fair studies were: BOD-18.7 mg/L, COD-99.5 mg/L, TOC-33.0 mg/L, pH 8.4, hardness 235.2 mg/L, TSS033.0 mg/L, total phosphorus-5.6 mg/L, and nitrite, nitrate, ammonia and organic nitrogen-0.15 mg/L, 0.06 mg/L, 23.9 mg/L, and 5.6 mg/L, respectively. However, there were periods when the wastewater quality decreased to that of a poor quality undisinfected secondarily treated domestic wastewater.

3. Neither the wastewater quality nor the slight changes in the wastewater quality as measured by traditional chemical/physical parameters appeared to have an impact on the generation or transport of microbiological aerosols in this study.

4. A strong relationship was observed among TOC, COD, and BOD in determining the overall quality of wastewater at the site. The significance level of the correlation between TOC and BOD was 0.006, and for the other pairs was less than 0.001.

5. Pathogenic bacteria and viruses were found consistently in the effluent samples, and coliphage were found in all effluent samples. A wide range of levels of these microbial components was found. Concentration levels routinely varied by one order of magnitude and variation often approached two orders of magnitude.

B. Methodology

1. The quantitative evaluation of microbiological wastewater aerosols during field studies requires high-volume sampling equipment, competent personnel and extensive laboratory and logistical resources.

2. Studies conducted on the aerosol collection media, the temperature at which the samples are shipped, and the total time from collection to analysis were examined in detail in the laboratory. The results led to the design of adequate methods for sampling and analysis such that pathogenic organisms were found consistently.

3. Some difficulties were encountered in contamination of the high-volume aerosol samplers between aerosol runs. This problem appeared primarily in the standard bacterial plate count and *Pseudomonas* assays. Special care must be taken to adequately decontaminate high-volume aerosol samplers between aerosol runs.

4. The microbiological aerosol data varied substantially in quality and informational content. Accordingly, a suitable aerosol data weighting procedure was employed, according to consistent rules, in conducting the aerosol factor analyses.

5. There is substantial imprecision using the methods employed in this study for measuring microbiological concentrations in aerosol samples. The aerosol measurement coefficients of variation were 17% for dye, 50% for total coliform and standard bacterial plate count, 58% for fecal coliform and *Pseudomonas*, 60% for *Clostridium perfringens*, 73% for coliphage, 74% for *Klebsiella*, 77% for fecal streptococci, and 81% for mycobacteria. While the microbiological aerosol variation due to field sampling sources is considerable, even more variation was caused by analytical sources such as sample processing, shipping, and laboratory procedures. Relatively little of the analytical variability is reflected in replicated analyses, which is the usual manner of reporting analytical variation.

6. A special study of respiratory viruses in wastewater found confirmed viruses in five of the forty roller tubes cultured. Typing disclosed that four of the five tubes contained ECHO virus 6, while the other viral isolate could not be identified. Echoviruses 6 may occur as either a respiratory-tract virus or as an enteric virus. The failure to isolate purely respiratory viruses in the Pleasanton wastewater confirmed our suspicion that the likelihood of finding respiratory viruses in wastewater is very small.

7. Reliable enterovirus aerosol concentrations can be detected by the methods employed in the two special virus aerosol runs conducted at Pleasanton. The measured enterovirus aerosol concentrations obtained, 0.011 pfu/m^3 and 0.017 pfu/m^3, were 1-1/2 orders of magnitude higher than was expected based on the measured wastewater concentrations during these runs.

8. At sites with aerosol source strengths similar to the Pleasanton site and with sampling and assay methods currently available, it is generally not advisable to conduct microbiological aerosol sampling at distances beyond 200 meters from a wastewater aerosol source.

9. In the quality assurance aerosol runs for systematic sampler differences, it was concluded that after correcting for the air flow rates, there was no systematic bias in microbiological collection efficiency among the high-volume samplers evaluated.

10. An acceptable state-of-the-art procedure extending previous models (1,2,3,4) has been developed for the estimation of microorganism aerosol concentrations in wastewater aerosol downwind from a spray irrigation site. The microbiological dispersion model developed permits the prediction of downwind aerosol concentrations of specific pathogen and indicator microorganism groups emanating from sprayed wastewater aerosols. This multiplicative model, $P = D \bullet E \bullet I \bullet e^{\lambda t}$, incorporates a diffusion factor D for which any applicable standard atmospheric dispersion model can be used; a wastewater aerosolization efficiency factor E that depends upon atmospheric and operating conditions; and microbiological impact and viability decay (die-off) factors I and $e^{\lambda t}$ which depend upon the microorganism group and atmospheric conditions. If allowance is made for the imprecise nature of microbiological aerosol data, this multiplicative model appears adequate to represent microbiological dispersion.

11. Prediction by the microbiological dispersion model of the pathogenic microorganism concentrations from wastewater aerosol sources to which downwind workers and nearby residents are exposed is the most promising method of determining their level of pathogen exposure. However, the model has been validated only to downwind distances of about 100 meters.

C. Aerosol and Wastewater Microbiology

1. Prior to selecting the test organisms for a study of this nature (or for the microbiological monitoring at a spray irrigation site) it is essential that several site specific screens of a wide variety of organisms (both pathogens and indicators) be conducted.

2. Over the ranges of the effluent microorganism concentrations obtained during sampling at Pleasanton (from one order of magnitude for coliphage and total coliform to well over two orders of magnitude for *Pseudomonas* and *Clostridium perfringens*), there are only the most tenuous of relationships between some pathogenic organisms and some indicator organisms. For all practical purposes the use of indicator organisms as a measure of specific pathogen levels in wastewater is invalid.

3. The geometric mean aerosol concentrations obtained at 50 meters downwind of the wetted spray area were:

standard bacterial plate count	460/m^3
total coliform	2.4 MFC/m^3
fecal coliform	0.37 MFC/m^3
coliphage	0.38 PFU/m^3

fecal streptococci	0.61 CFU/m^3
Pseudomonas	34.CFU/m^3
Klebsiella	<5. CFU/m^3
Clostridium perfringens	0.9 CFU/m^3
mycobacteria	0.8 CFU/m^3
enteroviruses (3 and 5 day)	0.014 PFU/m^3

Individual aerosol measurements frequently differed by more than an order of magnitude from these mean values.

4. Limited particle size data obtained with two-stage Andersen samplers showed a substantial portion in the respirable range. The median precent respirable particle values downwind of the spray line were 44 percent for total count and 74 percent for total coliform. In general, there was a higher percentage of respirable particles at close downwind distances (5 to 25 meters), than at background and farther downwind distances. These meager data is in general agreement with more thorough particle size studies performed at other sites(5,6,7). Particle size was not considered in the mathematical modeling.

5. The use of most of the traditional organisms for monitoring wastewater aerosols results in a gross underestimation of pathogen levels. Total coliform, fecal coliform, coliphage, and standard bacterial plate count, which are commonly used as indicators of wastewater pathogens, do not survive wastewater aerosolization nearly as well as do the pathogens studied.

6. One of the better indicators for wastewater aerosol monitoring may well be fecal streptococci due to the relative ease of the assay, the levels found in the wastewater, its relative hardiness during aerosolization, and its relatively low viability decay rate. However, an apparent problem was the occasional presence of fecal streptococci in aerosols due to non-wastewater sources.

7. Although *Klebsiella* was relatively prevalent in the wastewater, it was far less prevalent in the wastewater aerosol. It appears that *Klebsiella* die off rapidly during the aerosolization process. This finding is in contrast to data seen in the literature which consistently report *Klebsiella* as the predominant pathogen found in the air near spray irrigation sites and near sewage plants. More confirmation steps were used in this study than in earlier studies. If the confirmation steps had been stopped at the point used by other investigators, more values would have been reported as *Klebsiella* when, in fact, they were primarily other organisms of the mucoid type.

8. There was no significant difference in the coliform or coliphage concentration in corresponding effluent samples taken from a spray head during the aerosol runs and from the effluent composite samples at the pond pump. The standard bacterial plate count, however, was significantly higher in the spray field samples. The correlations of the spray field and pond composite microorganism concentrations were generally significant, but not adequate for prediction.

9. The median aerosolization efficiency E obtained for the Rainbird® impact sprayers over 17 dye runs during Phase II at Pleasanton was 0.33%. There was over an order of magnitude of variation in aerosolization efficiency estimates from the tenth percentile (0.09%) to the ninetieth percentile (1.8%). Eighty percent of this variation in aerosolization efficiency at Pleasanton appears to result from changes in meteorological conditions (air temperature, wind velocity, and solar radiation) that affect the evaporative capability of the air.

10. The median impact factor estimates I for the microorganism groups studied were 0.13 for fecal coliform (13% survive aerosol impact), 0.16 for total coliform, 0.21 for standard bacterial plate count, 0.34 for coliphage, 0.89 for mycobacteria, 1.2 for *Clostridium perfringens*, 1.7 for fecal streptococci, 14 for *Pseudomonas*, ca. 10 for three-day enteroviruses (mostly polioviruses), and ca. 40 for all (3-day and 5-day) enteroviruses. Most individual impact factor estimates were quite imprecise, reflecting the imprecision of the microbi-

ological aerosol concentration measurements. Since the middle range of impact factor values (fortieth to sixtieth percentiles) for each microorganism group were quite consistent, they are considered to be characteristic of the microorganism groups' typical survival through aerosol impact.

11. As indicated by impact factors exceeding 1.0, the enteroviruses and some hardy bacterial pathogens are frequently found in wastewater aerosols at higher concentrations than could be expected based on their wastewater concentrations. The survival, masking, and mechanical splitting hypotheses discussed later may collectively explain this phenomenon.

12. The indicator microorganism groups, especially total coliform and fecal coliform, experience more consistent and rapid die-off with aerosol age than do the pathogenic bacteria evaluated. The viability decay rates λ for total coliform and fecal coliform were more rapid, more reliable, and more frequently detectable than those of the other microorganism groups. The median viability decay rates were $-0.032s^{-1}$ for total coliform and $-0.023s^{-1}$ for fecal coliform. Viability decay was less rapid for coliphage, *Clostridium perfringens*, and standard bacterial plate count and its effect could only be ascertained within 100 meters on about half the runs. Viability decay could seldom be ascertained for fecal streptococci, mycobacteria, and *Pseudomonas*. No attempt was made to determine the viability decay of enteroviruses.

13. The range of impact factor estimates for each microorganism group was broad, generally covering two orders of magnitude from the tenth percentile to the ninetieth percentile. The detectable viability decay rates of each microorganism group also covered a wide range. Preliminary analyses suggest ambient conditions such as low relative humidity, high wind velocity, and a large temperature differential between wastewater and air may reduce the initial survival, i.e. produce low impact factor values I. Viability decay may be more rapid with high solar radiation, high temperatures, and middle or low relative humidity. Research is needed to quantify the relationships of impact factor variation and viability decay rate variation to the ambient atmospheric conditions for the specific microorganism groups.

14. The accuracy and precision of microbiological dispersion model predictions have, in general, been validated to 100 meters downwind of spray sources of unchlorinated wastewater aerosols. Most model predictions (e.g., 77 percent for standard bacterial plate count, 71 percent for total coliform, and 80 percent for coliphage) were within a factor of five of the net measured aerosol concentrations evaluated. Considering the imprecision and cost of measuring microorganism aerosol concentrations from spray irrigation by field sampling, using predictions of the microbiological dispersion model supplemented with minimal field sampling does appear to be a preferable alternative to extensive field sampling when the sprayed wastewater does not contain residual chlorine.

D. General

Results of this study indicate that pathogenic organisms do survive as aerosols from the spray irrigation of wastewater and can be transported downwind into nearby populated areas. Until such time as more information is developed on the infectious dose for a particular organism, effective control of pathogens must be accomplished prior to spray irrigation to minimize this risk. The most reliable means of reducing potential health hazards from pathogenic aerosols is by disinfecting the wastewater before spraying. Until the necessary dose-response relationships are developed neither the level of aerosolized microorganisms that constitute a hazard nor the degree of required disinfection can be specified.

II. RECOMMENDATIONS

1. Dose-response relationships need to be developed for the pathogenic microorganisms prevalent in wastewater aerosols. The available techniques include epidemiological studies of human populations, sentry animal studies, laboratory animal studies, clinical studies, and/or professional judgment. Epidemiological studies may be the best technique. The evaluation of spray irrigation as a viable means of disposing of wastewater will remain incomplete until such dose-response relationships can be established.

2. A reliable procedure is needed for selected values of the model parameters I and λ when predicting microorganism aerosol concentrations using the microbiological dispersion model. There are preliminary indications in our data supported by considerable published data that the I and λ values for a microorganism group depend highly upon ambient atmospheric conditions. A careful multivariate analysis of the existing values of I, λ, and the meteorological conditions for each Pleasanton run should be conducted. The resulting relationships of microorganism I and λ values as a function of ambient meteorological conditions would provide a substantive basis for their selection in model prediction applications.

3. To assess the predictive capacity of the microbiological dispersion model, a thorough evaluation of the model should be conducted through a limited field sampling program using the Pleasanton study methods at other sites. The enhanced model to be evaluated should incorporate the I and λ selection procedure discussed in the preceding recommendation. The model evaluation conducted herein needs to be extended because the field and sampling methods differed from the Pleasanton methods, pathogens were not assayed at sites other than Pleasanton, and no adequate I and λ parameter selection procedure existed.

III. STUDY DESCRIPTION

A. Statement of the Problem

Application of wastewater to land is perhaps the oldest method of disposing of wastes by man. The more recent trend has been to discharge treated and untreated wastes into streams, lakes, and oceans. During the past several years, there has been increased interest in applying treated wastewater to land as an alternative to discharging into surface waters, in order to avoid the contamination of these bodies of water. The Environmental Protection Agency (EPA) has in recent years required that applicants for federal construction grants (Section 201) for wastewater treatment facilities show in their request that they have considered the application of wastewater to land as an alternative.(8) More recently, the EPA has announced plans to press vigorously for the recycling of wastewater via land application.(9) There are several advantages to applying treated wastewater to land, including re-use of the water, avoiding contamination of surface waters, and return of nutrients to the soil. Many small communities primarily in arid regions, have long employed wastewater land-application systems as a means of water conservation and waste disposal. During the past several years, a large metropolitan area, Muskegon County (Michigan), has completed a project involving biological treatment, storage lagoons, disinfection, and spray irrigation for disposal of wastewater from a population of more than 170,000.

Land application of wastewater can be accomplished by several methods, which can be categorized as overland flow, rapid infiltration, and slow infiltration. Spray irrigation is perhaps the most popular method of wastewater application because it can be applied to a wide variety of land sites and the irrigation apparatus can be moved readily from one location to another. For many municipalities, both small- and medium-sized, spray irrigation is the most attractive means for land application of treated wastewater. Recreational areas such as parks, golf courses, and highway right-of-ways, can be irrigated. Irrigation of land sites immediately adjacent to the waste treatment facility for growing of grass cover is also an economically and environmentally attractive use of the wastewater. The applicability of spray irrigation to a much larger segment of waste treatment facilities will necessitate that these spray sites be located adjacent to the facilities and, therefore, probably near populated areas. Certainly, application of wastewater to recreational areas by spray irrigation has a high potential for contact between the wastewater aerosol and individuals, both the spray applicators and surrounding populations.

A number of investigators have raised questions regarding the health and hygienic aspects of application of wastewater to land, especially by spray application. These investigators include Wellings, *et al.*,(10) Sorber and Guter,(11) Parson, *et al.*,(12) Katzenelson and Teltch,(13) and Elliott and Ellis(14).

Wellings, *et al.*, cautioned the utilization of spray irrigation of wastewater because of the many unknowns regarding the fate of pathogenic bacteria and especially viruses. These authors' studies have been primarily directed at possible contamination of ground water by viruses following spray application of treated wastewater. Sorber and Guter examined the literature regarding the health aspects of land application of wastewater by spray irrigation and concluded that there was a probability of humans inhaling pathogenic aerosols near a spray irrigation site. They recommended that research be performed to determine the viability of human pathogenic microorganisms present in biological aerosols from spray irrigation of wastewater. They also suggested that there be a determination of the type of spray distribution system, nozzles, and associated operating pressures necessary to minimize the health hazards from biological aerosol formations.

Earlier work by investigators such as Ledbetter and Randall(15) showed that activated sludge treatment facilities operations were sources of aerosolized bacteria, some of which might be pathogenic. These bacterial microorganisms were from aerosolized wastewater in the aeration basins present in the treatment facilities. It is, therefore, quite probable, as pointed out by Sorber and Guter, that spray application of treated wastewater with various types of spray irrigation equipment and with different spacing and type of nozzles would significantly influence the quantities of aerosols formed. The aerosols generated by the sprinklers might contain pathogenic bacteria and viruses, and they might consist of particles in the size range of 0.01 to 50 microns.[16]

From the data seen in the literature, it appears that spray irrigation of treated wastewater will result in formation of aerosols which may contain pathogenic microorganisms. Inhalation of pathogenic microorganism may lead to infection. This is a major source of the public health concern for this method of wastewater disposal and the reason for conducting this research. From limited data, it appears that some of these organisms will remain viable for extended periods of time and may be carried by winds for considerable distances from the spray irrigation sites.

An environmental monitoring effort was performed by Katzenelson and Teltch near spray irrigation fields in Israel. The effluent sprayed on these fields was from partially-treated undisinfected municipal wastewater and levels of coliform bacteria in the effluent were approximately the same as those seen in raw wastewater present in the United States. Coliforms were measured in aerosols and a portion of these aerosol samples was further examined for the presence of *Salmonella*. They found elevated levels of coliform bacteria 300 meters downwind from the spray irrigation site. In one of the aerosol samples collected at 600 meters downwind, they found an isolate of *Salmonella*. They calculated that an individual 100 meters downwind from the wastewater sprinkler line would inhale approximately 36 coliform bacteria in a period of 10 minutes. These authors concluded from these preliminary results that there may be a relatively neglected potential danger to agricultural workers and neighboring settlements from the use of spray irrigation wastewater. They stated that proper disinfection of wastewater for irrigation purposes may be the most effective means of reducing this risk.

Sorber, *et al.*,[17] conducted an extensive environmental monitoring effort at a field site in Arizona where chlorinated secondary municipal effluent was used to irrigate a golf course. These authors performed field testing of both chlorinated and unchlorinated effluent to enumerate bacteria present in the effluent, to determine the fraction of wastewater entering the aerosol state, and to determine the survival in aerosols of total aerobic, indicator, and selected pathogenic bacteria. *Klebsiella* was the most commonly found pathogen, with fecal streptococci found in some samples. When chlorinated effluent (versus unchlorinated effluent) was sprayed, much lower levels of pathogenic bacteria were found in the aerosol samples, although the reduction was less than expected from comparison of pre- to post-chlorinated wastewater bacteria levels. Elevated levels of bacterial aerosols were measured out to 200 meters downwind of the spray line. It was estimated that bacterial levels would be present above background up to 500 to 1800 meters for unchlorinated wastewater, depending on meteorological conditions. A prediction model was developed in the course of this study for estimating concentrations of microbiological constituents downwind of the spray line. Components of the model included meteorological and other measurements taken downwind as well as the concentration of the microorganism in the effluent. In the discussion on microbial aerosols from the spray irrigation of wastewater, these authors point out that the factors of prime interest are: (1) the biological aerosol concentration at any distance from the source, (2) the buffer zone required to reduce such aerosols to near background levels, and (3) the effect of terminal disinfection or other polishing wastewater treatments on aerosol strength. The aerosol levels of viable microorganisms are dependent upon the levels of these organisms in the wastewater, the proportion of wastewater that is aerosolized, the volume of water sprayed per unit time, the aerosol decay rate and the atmospheric stability, wind speed, and other meteorological parameters. These authors defined aerosolization efficiency as the proportion of wastewater that becomes divided into droplets sufficiently small to remain in an airborne state. They found a statistically significant increase in the mass median diameter of viable bacteria-bearing particles with distances downwind of the spray irrigation sites. They postulated that this may indicate a lower rate of decay for bacteria associated with the larger particle size material. An alternative mechanism suggested was that the droplets receive pre-existing clumps or aggregates of many bacteria cells which tend to form larger solid nuclei. There was no indication that the particle size distribution for a viable airborne bacteria recovered from chlorinated effluent aerosols differed from those recovered in experiments without chlorination. They suggested that terminal disinfection is probably a more practicable and cost effective means of limiting the problems with pathogenic aerosols than are buffer zones.

Little information is available concerning the possible health effects following exposure to the low levels of bacteria and possible viruses that are present in ambient air near spray irrigation facilities. It is known that the inhalation of specified quantities of pathogenic bacteria or viruses can infect persons, but epidemiological data concerning a definable health effect following exposure to aerosols from a wastewater treatment facility are quite limited. Clark, *et al.* (18) reviewed the literature concerning the possible health effects of persons exposed to municipal wastewater via physical and aerosol routes of exposure. The review covered microbial aerosols from activated sludge, trickling filter, and spray irrigation of wastewater. They found that no correlation had been made between specific microorganism levels and the incidence of selected diseases. They reported on a 3-year prospective epidemiology-serology study to be performed in their laboratory involving sewage maintenance workers and an appropriate control group. This study has been expanded to include sewage plant operators and appropriate controls for study of effects of the exposure to aerosols from wastewater plant operations. Overall, the prospective study is aimed at determining the possible health effects from exposure to relatively high levels of wastewater via physical and oral ingestion of wastewater for the sewage workers and to inhalation of aerosols for the plant operators. These studies include collection of symptomatology data, blood, urine, throat swabs, and stools for examination for viral, bacterial, and parasitic isolation, as well as a detailed serological analysis. The results of this study should provide indications of possible health effects at relatively high levels of exposure to adult male populations.

A retrospective epidemiological study of communicable diseases associated with spray irrigation of wastewater was performed near settlements in Israel by Katzenelson, *et al.*(19). These authors examined the incidence of enteric communicable diseases in 77 kibbutzim (agricultural settlements) practicing spray irrigation with partially-treated, nondisinfected wastewater. These data were compared with that from 130 kibbutzim not practicing spray irrigation. They found that the incidence of Shigellosis, Salmonellosis, typhoid fever, and infectious hepatitis were two to four times higher than for those communities not practicing spray irrigation. They also noted that for the months in which there was no spray irrigation, i.e., the winter months, there were no differences between the study populations for these enteric diseases. The study populations (positive) lived from 100 to 3000 meters from the spray irrigation field. This retrospective study provides some epidemiological evidence for an increased risk for enteric communicable diseases among populations living near sites spray irrigating with municipal wastewater. The study does not identify the transmission route, that is, via physical or aerosol exposure, nor does it directly relate spray irrigation with these elevated diseases. The operators of the spray irrigation facilities live in these kibbutzim; thus, one pathway might be via physical exposure to the wastewater irrigation site workers and via the clothes of the irrigation site workers when they return home. These authors point out the need for caution in the utilization of poorly-treated wastewater via spray irrigation near residential areas. A follow-up study is underway.

A prospective environmental epidemiological study by Carnow, *et al.*, at the University of Illinois (EPA Grant R-805003-01) is nearing completion. This environmental epidemiological study was performed near an existing activated sludge treatment facility located in Skokie, Illinois. This effort has similarities to the study (to be discussed below) conducted by Southwest Research Institute in the type of monitoring performed. However, a major difference is that it was located near an existing wastewater treatment facility, whereas the study conducted by Southwest Research was designed for a new plant with a before-operational monitoring effort and a monitoring effort after the plant was in operation. The objective of Skokie study was to collect health effects data relative to the operation of the plant and to examine these data with regards to health effects related to the distance the population lives from the plant. Environmental monitoring was performed and an assessment of the bacterial microorganisms present around this plant was made. This study had 269 households living from about 600- to 800-meters from the center of the wastewater treatment plant.

An environmental monitoring and a prospective epidemiological study was performed by Johnson, *et al.*(20) of Southwest Research Institute for a new activated sludge treatment plant located near Chicago, Illinois. The purpose of this study was to identify possible health effects which might be attributed to the operation of an activated sludge wastewater treatment plant. The program was to involve three independent modes of investigation of a new activated sludge treatment plant prior to its operation and after its initial operation:

- Environmental monitoring in the vicinity of the site to determine the source and transport of indicator and pathogenic microorganisms and of trace metals.
- A health survey of a cross section of the households located within a 5-km radius of the plant aeration basin to examine the incidence of respiratory and intestinal diseases and symptoms.
- Analysis of clinical specimens from more than 200 participants residing within 3.5 km of the plant to determine viral antibody titers, to isolate pathogenic bacteria, viruses, and parasites, and to measure trace metal concentrations.

Each of the above was designed to determine whether the data followed a pattern that might implicate the wastewater treatment plant as a health hazard. The results showed that for the trace metals studied (cadmium, lead, mercury, and zinc), only mercury appeared to be elevated as a result of the wastewater treatment plant and that mercury elevation was not transported away from the plant. Also, the levels of these trace metals were not elevated in the soil and water samples collected in neighborhood residential areas relative to background levels. The plant did appear to be a source of indicator bacteria, coliphage, pathogenic bacteria, and enteroviruses emanating from its aeration basins. However, the levels of these microbial agents in air, soil, and water samples in the neighboring residential areas were not distinguishable from background levels. From the patterns observed in the household health survey, there was an increased incidence of skin disease and in the symptoms of nausea, vomiting, general weakness, diarrhea, and pain in chest on deep breathing among residents living close and in prevalent downwind directions from the wastewater treatment plant. Viral antibody tests and attempted isolation of many pathogenic bacteria, parasites, and viruses, however, yielded no evidence of an adverse wastewater treatment plant effect. The findings overall obtained in this study did not detect a public health hazard for populations living beyond 400 meters of this well-operated wastewater treatment plant. The lack of sufficient participants living close to the wastewater treatment plant precluded an assessment of the possible hazard near the plant. The study does confirm results seen in previous studies of wastewater treatment plants in that the plant is a source of pathogenic bacteria and possible viruses; however, levels above background were not obtained at distances beyond approximately 300 meters. Of the pathogenic bacteria monitored in aerosol samples (fecal streptococci, *Salmonella*, *Shigella*, *Pseudomonas*, and *Klebsiella*), only *Pseudomonas*, fecal streptococci, and *Klebsiella* were found. *Pseudomonas* was present in virtually all aerosol samples, while fecal streptococci and *Klebsiella* were found in only a few. One aerosol sample taken 300 meters downwind was positive for enteroviruses (poliovirus type III).

A recent review by Akin, *et al.*,(21) of the health hazards associated with the treatment and disposal of wastewater effluents and sludge, reports that in the absence of adequate epidemiological data to evaluate the potential health hazard from pathogens applied to soil, the monitoring for the occurrence of the pathogens in the environment must be the primary public health measure. These authors also pointed out the possible health hazards of parasites in the application of treated wastewater and sludge to land. In particular, the protozoan of greatest health interest in the past several years has been *Giardia lamblia*. Cysts from this protozoan are able to survive many of the wastewater and sludge treatment processes and only a small number of cysts are necessary to infect humans. However, because of their size, it is questionable whether the cysts can travel as aerosols for large distances.

From the review of the literature on environmental monitoring, it is apparent that treated wastewater can contain significant quantities of microorganisms and pathogenic bacteria and viruses. It also appears that various processes involved in wastewater treatment facilities can create aerosols of these wastewaters containing viable microorganisms. Spray irrigation appears to offer the greatest potential for aerosolization for bacterial organisms. Some evidence is indicated that bacteria are present in aerosols from these sites. Bacterial organisms are present in air around spray irrigation facilities at distances up to at least 300 meters downwind and model projections indicate that these aerosols could be present above background out to several kilometers. The studies also indicate that various meteorological conditions can have a significant impact on the viability of these organisms in air following aerosolization. In general, high wind conditions, high humidity, and low solar radiation tend to enhance the viability of bacterial aerosols.

B. Study Background

This research effort was jointly funded by the U.S. Army Medical Research and Development Command, Fort Detrick, Maryland, and the Health Effects Research Laboratory of the Environmental Protection Agency, Cincinnati, Ohio. Each of these governmental organizations needs definitive data regarding the possible health effects associated with spray irrigation of municipal wastewater. The Army has a number of installations throughout the United States and foreign countries where disposal of municipal wastes is required. Application of treated wastewater to land, especially via spray irrigation, is an attractive means of final disposal and serves as an alternative to discharge into a watercourse. This permits the reuse of the wastewater for irrigation purposes and avoids the discharge of wastes into rivers, lakes, and oceans. As stated earlier, the Environmental Protection Agency has been an advocate of land application of treated wastewater as an alternative to discharging into surface waters. During recent times, the EPA has announced that it intends to press vigorously for the use of construction grant funds for wastewater treatment plant facilities to be directed at application of treated wastewater to land. The funds obligated for construction of new wastewater facilities in the United States are in the billions of dollars and the EPA has both the authority and the responsibility to insure that these facilities are constructed to effectively treat wastewater in the most economical and cost-effective means possible. In addition, the EPA must insure that the health of people in communities near these facilities is protected and that surface and ground waters are not significantly contaminated by chemical or biological pollutants. As discussed earlier, spray application of wastewater is one of the most attractive land application methods from an engineering standpoint. It does, however, offer the possibility that aerosols, formed during spraying operations, can be transported to nearby human populations and that some portion of the population will be infected by wastewater-associated pathogenic microorganisms. The initial objective of this study was to collect information regarding the types and quantities of microbial organisms emanating from a spray irrigation facility and to study these concentrations downwind of the spray facility into a populated area. A potential extension of this effort would examine the health status of a population adjacent to the spray fields as compared with a suitable control population. The initial monitoring study was designed such that sufficient numbers of samples would be collected and analyzed, along with a sound quality control program so that statistically valid data would be obtained. The overall study would provide both the U.S. Army and the EPA with much of the data necessary to provide design criteria for construction and performance of spray irrigation facilities. This is extremely important since it is apparent that the utilization of spray irrigation of treated municipal wastewater could have numerous advantages over conventional wastewater treatment for a wide section of the United States.

This project was performed in three phases. At the completion of each phase, an analysis of the data was made and a report prepared, with the final design of the next phase of study dependent upon the results of the previous phase. Thus, there was considerable flexibility during the conduct of this effort to adjust the program's emphasis on the basis of gained knowledge.

Phase I was designed to select a suitable site for the conduct of the study and to develop the optimum methods for sampling and analysis of wastewater and aerosol samples for various types of bacteria, viruses, and chemical constituents. Phase II was designed to perform extensive environmental monitoring of the selected spray site to cover a period of some eight months. This phase would accurately measure the quantities and types of pathogens and other constituents under a variety of meteorological conditions and a range of source strengths of these materials in the wastewater. Phase II was divided into two parts: one conducted prior to a county fair held near the selected site, labeled "Pre-Fair", and the second performed afterward, labeled "Post-Fair". In general, the objectives of the Pre-Fair portions of Phase II were aimed at characterization of the aerosols for bacterial and viral microorganisms within 100 meters of the spray fields. Environmental monitoring during the Post-Fair phase emphasized sampling and analysis of selected pathogenic microorganisms, with aerosol monitoring conducted at distances up to 600 meters from the spray fields, extending into the populated areas. Phase III of this program is an optional phase to be directed at examining the potential human health effects of the spray irrigation facility. The study would examine a population living near the spray irrigation facility and compare their health status with a suitable control population. A decision to conduct Phase III has not been made but will follow examination of the data obtained during Phases I and II. The findings for the Phase I study are summarized in the Phase I report published in December 1975.(22)

C. Phase I Summary

Following a telephone survey of known wastewater spray irrigation facilities in the United States and an on-site survey of two locations, the wastewater land treatment system in Pleasanton, California, was selected for evaluation. The site selection criteria are listed in the Phase I report, but one of the important requirements, and one of the most difficult to satisfy, was that a suitable population had to live within one mile of the spray irrigation facility. The Pleasanton, California site met most of the desired criteria, including an adequate study and control population.

The Phase I results indicated that some of the initially-selected methods for sampling, sample transport, and analysis were inadequate to accurately determine the levels of pathogenic bacteria and viruses in both effluents and aerosols. Measurement of indicator organisms and other chemical constituents showed that the wastewater at this site was of a quality to be expected of a plant not practicing disinfection.

It was apparent from the preliminary aerosol sampling conducted during Phase I that the micrometeorology of the site would complicate the overall air sampling protocol and the interpretation of the data. No significant daily or hourly changes were seen in the chemical or biological constituents measured in the effluent, apparently due to the utilization of two aeration ponds at the end of the treatment plant that appeared to dampen cyclic changes which might have occurred through the plant. This made the environmental monitoring study easier since a rather uniform quality of wastewater was being sprayed.

One of the important findings of Phase I was that high-volume aerosol samplers were essential for measurement of pathogenic microorganisms present in the air downwind from the spray irrigation site. Samplers such as the Andersen and AGI, although perhaps having similar sampling efficiencies, would not sample sufficient quantities of air to provide the necessary sensitivity. It was concluded that aerosols generated from the adjacent secondary wastewater treatment plant itself should not complicate the study of aerosols from the spray irrigation fields because the head work, aeration chamber, and trickling filter were all covered to control odors. There was a possibility that the aeration ponds, also adjacent to the spray fields, could generate aerosols and confound the field study results.

D. Phase II Objectives and Design

1. Phase II Objectives

As stated above, Phase II was divided into two subtasks, Pre-Fair and Post-Fair. The Pre-Fair monitoring effort was performed so it would be completed prior to the beginning of a large county fair held in Pleasanton, California in the summer months. During the fair, a large influx of wastewater from animal holding facilities produced a typical wastewater effluent and no monitoring was to be performed during the fair or immediately afterwards. The Post-Fair monitoring effort was conducted after the effluent had returned to more typical characterization.

The objectives of Phase II are listed below for both Pre-Fair and Post-Fair.

a. *Pre-Fair Objectives*

The following is a list of the primary objectives to be accomplished during the Pre-Fair activities of Phase II.

Microbial Aerosol Runs

- begin evaluation of factors affecting microbiological aerosol levels within 100 meters of the spray source.

Dye Runs

- determine the aerosolization efficiency range of the sprinkler irrigation machinery used at the Pleasanton site.

Effluent Samples

- determine in-depth pathogen screen
- assess validity of using the common measures of wastewater microbiological quality (standard bacterial plate count, total coliforms, fecal coliforms) as indicators of the pathogen levels of the effluent.
- examine relationships between the microbiological and chemical water quality constituents.

Quality Assurance

- determine accuracy and precision of laboratory analyses
- determine if there are systematic differences in high-volume sampler collection efficiency.

b. *Post-Fair Objectives*

- identify and quantify the factors affecting microbiological aerosol levels over a wide range of meteorological conditions.
- develop a general microbiological dispersion/die-off model for appropriate microorganism groups that can be applied at other wastewater spray irrigation sites.
- predict the downwind microbiological aerosol concentration in the residential areas adjacent to the spray fields, relative to background levels.

2. Phase II Design

The types of samples obtained in the Phase II study (Pre- and Post-Fair) are summarized in Table III. D-I.

Table III.D-1.
SUMMARY OF PHASE II DESIGN

	Pre-Fair					Post-Fair		
Wastewater Samples	Daily Composites	Microbiological Run Composites	Dye Run Grabs	500 ml Grabs	Large Volume (20l) Grabs	Microbiological Run Composites	Dye Run Grabs	Large Volume (20l Grabs)
Chemical Analyses								
Total Chlorine	X			X				
Free Chlorine	X			X				
pH	X					X		
Total Organic Carbon (TOC)	X					X		
Total Solids	X							
Total Suspended Solids (TSS)	X					X		
Biochemical Oxygen Demand (BOD)	X*					X		
Chemical Oxygen Demand (COD)	X*					X*		
Total Phosphorus	X*					X*		
Nitrite Nitrogen	X*					X*		
Nitrate Nitrogen	X*					X*		
Ammonia Nitrogen	X*					X*		
Organic Nitrogen	X*					X*		
Conductivity						X		
Rhodamine Dye			X				X	
Microbiological Analyses								
Standard Bacterial Plate Count	X	X			X	X		X
Total Coliform	X	X			X	X		X
Fecal Coliform	X	X			X			
Coliphage	X	X			X	X		X
Fecal Streptococci		X			X	X		X
Pseudomonas		X			X			
Klebsiella		X			X			
Clostridium perfringens		X			X			
Mycobacteria					X	X		X
3-day enterovirus		X			X			
5-day enterovirus		X			X			
Pathogen screen					X			X

Table III.D-1 (cont'd)

Aerosol Samples	Pre-Fair Microbiological	Pre-Fair Dye	Pre-Fair Quality Assurance†	Pre-Fair Large Volume‡	Post-Fair Microbioloigcal	Post-Fair Dye	Post-Fair Quality Assurance	Post-Fair Special Virus
Microbiological Analyses								
Standard Bacterial Plate Count	X		5	X	X		X	
Total Coliform	X		5	X	X		X	
Fecal Coliform	X		5	X				
Coliphage	X		2	X	X		X	
Fecal Streptococci	X		2		X			
Pesudomonas	X		2					
Klebsiella	X		2					
Clostridium perfringens	X		2					
Mycobacteria					X		X	
3-day enterovirus	X							X
5-day enterovirus	X							X
Pathogen screen				X				
Rhodamine Dye Analyses		X				X		

---

* not run on all samples

† various analyses, number of runs indicated

‡ pooled collection fluid from all samplers

E. Participating Organizations and Principal Personnel

The research effort documented in this report has been conducted by Southwest Research Institute with the significant support and contributions of a number of other organizations. The following is a listing of participating organizations:

1. Southwest Research Institute (SwRI)
   San Antonio and Houston, Texas

2. The University of Texas at San Antonio (UTSA)

3. The Pacific Environmental Laboratory (PEL)
   San Francisco, California

4. Naval Biosciences Laboratory (NBL)
   Oakland, California

5. Environmental Quality Analysts (EQA)
   San Francisco, California

6. Dugway Proving Ground
   Dugway, Utah

7. Manpower, Incorporated
   Hayward, California

8. Sunol Sewage Treatment Plant
   Pleasanton, California

9. H. E. Cramer, Incorporated
   Salt Lake City, Utah

The study site is located at the Sunol Plant, listed above, and a detailed description of the site and the principal personnel supporting this study at the site is presented in the following section of this report. Details regarding area of responsibility and principal participating personnel for organizations other than the Sunol Plant are presented in Table III.E-1. The organization directing the study is Southwest Research Institute and all other organizations listed are acting in support of SwRI in this study. All personnel listed are permanent professional staff at the various institutions, with the exception of those listed for Manpower, Incorporated. The personnel listed for Manpower, Incorporated are temporary employees hired for the field surveys. The field survey team, though temporary staff rather than permanent professional staff, exhibit the same high degree of professionalism as the permanent staff.

Table III.E-1.
PARTICIPATING ORGANIZATIONS AND PRINCIPAL PERSONNEL

Organization	Responsibility of Organization	Responsible Participants	Primary Responsibility of Participant
SwRI	Project direction and final results	D. E. Johnson, Ph.D.	Project director
		J. W. Register, Jr.	Direction of field activities
		D. E. Camann	Statistician
		R. E. Thomas	Statistician
		R. J. Prevost	Subcontracting and reports
		J. L. Gulinson	Meteorology
		J. M. Taylor	Air sampling
		H. J. Harding	Air sampling
		J. Salinas	Air sampling
		J. Trevino	Air sampling
		J. Paulk	Air sampling
UTSA	Analysis of coliphage pathogenic bacteria viruses	B. P. Sagik, Ph.D.	Direction of analysis
		C. A. Sorber, Ph.D.	Direction of analysis
		M. N. Guentzel, Ph.D.	Analytical methods
		B. E. Moore	Virology
PEL	Chemical analysis, indicator microbial parameters	T. Nakamura	Supervising chemist
		N. Harper	Bacteriologist
NBL	Consultant organization	M. A. Chatigny	Consultants in aerobiology
		H. Wolochow, Ph.D.	Consultants in aerobiology
EQA	Alternate laboratory used in quality assurance study	J. Tyler	Laboratory director
Dugway	Meteorological support	C. Spendlove, Ph.D.	Aerosol sampling
		E. Rengers	Meteorology
		J. Scudiri	Meteorology
Manpower, Inc.	Temporary employment firm used to hire field survey team	T. Rooney	Chemical technician
		P. Anderson	Air sampling
		J. DeNicola	Air sampling
		G. Langlois	Air sampling
		D. Lewis	Air sampling
		R. Purdie	Air sampling
		R. Stover	Air sampling
		B. Pruett	Air sampling
		D. Gaines	Air sampling
		J. Graham	Air sampling
		N. Houlding	Air sampling
		C. March	Air sampling
		G. Murdock	Air sampling
		E. Sternstein	Air sampling
		B. McLeod	Air sampling
		M. Sturgis	Air sampling
		L. Harrison	Air sampling
		R. Menzimer	Air sampling
		D. Wheaton	Air sampling
		J. Synder	Air sampling
		M. Mitchell	Air sampling
		M. Krause	Equipment maintenance and air sampling
H. E. Cramer, Inc.	Aerosol modeling and additional statistical support	K. Dumbauld	Direction of aerosol modeling
		A. Anderson	Aerosol modeling

IV. STUDY SITE

A. Site Description

1. Sunol Sewage Treatment Plant

As documented in the Phase I report, a water reclamation plant in the City of Pleasanton, California, was selected as the study site: the City of Pleasanton Sunol Sewage Treatment Plant.

A schematic of the study area is shown in Figure IV. A-1. A population with middle-class socioeconomic characteristics is located within one mile to the east/southeast of the plant. This population is located in a recently completed subdivision off Mission Drive. Mission Drive runs east-west, and the street begins on Sunol opposite the treatment plant. The prevailing winds in this area are from the southwest to northwest quadrant; thus, this inhabited area would be downwind of the spray fields. There is a population in this subdivision to conduct an epidemiological study, and there are also suitable control populations in Pleasanton with middle-class socioeconomic characteristics located more than 2000 meters from the spray fields. The people in the subdivision near the treatment plant live from 600 to 1000 meters southeast of the edge of the spray fields.

The Pleasanton water reclamation plant is under the control of the city government of Pleasanton, California. City personnel involved in the study are as follows:

City Manager	Clayton E. Brown
Assistant City Manager	Alan B. Campbell
Director of Public Works Field Services	H. Arnold Eaton
Public Works Field Superintendent	Arthur N. Monaco
Plant Foreman	John Wayneberg
Treatment Plant Operator	George Oxsen
Laboratory Analysis	Jerry Taylor

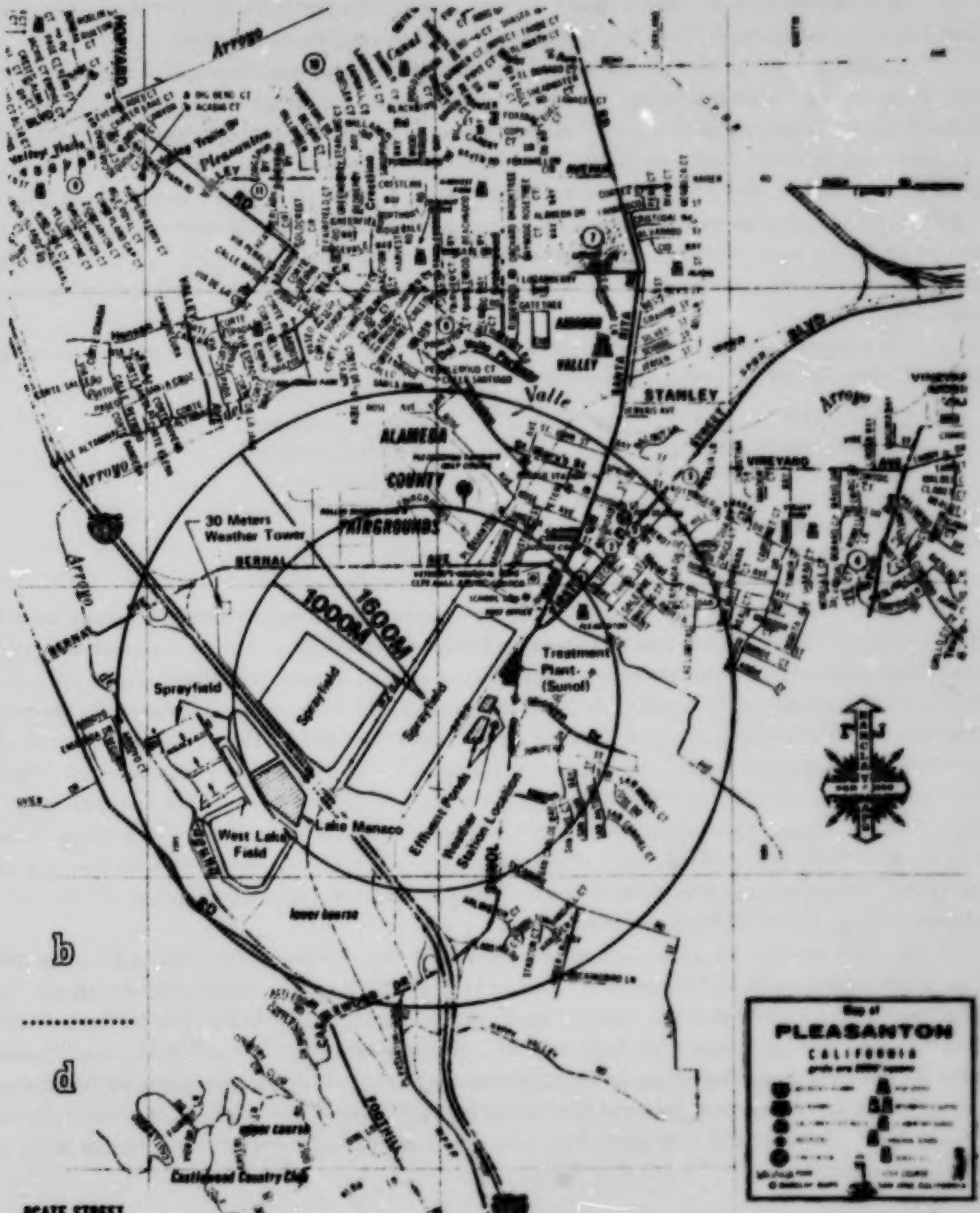
Arthur Monaco is directly responsible for the operation of the water reclamation plant, including the spray irrigation system. The city had no immediate (within one year) plans to change the operation of this treatment plant with respect to the spray irrigation of wastewater. The plant was modified just prior to the Pre-Fair study by the addition of an activated biofilter process (ABF) following the trickling filter to enhance the treatment system's biochemical oxygen demand (BOD) removal efficiency. The spray operation is nearly a "break-even" cost operation for the city because of the income it derives from the leasing of the irrigated pastures to cattlemen. The beef cattle which graze on the grass (44% alta tall fescue, 33% Ariki perennial rye, and 23% Potomac Grass Orchard) appear to grow well without supplemental food. The grazing of dairy cattle on the spray fields is prohibited. Beef cattle must wait seven days before grazing on fields that have been spray irrigated. The cattle are moved ahead of the sprayers and the normal rotation of the spayers through the fields ensures that a sufficient period of time has elapsed.

An average of 1.4 million gallons per day (MGD) of sewage is treated by trickling filtration and is stored in aeration ponds with a total retention volume of three million gallons. Approximately 600 gal./min. is recycled during irrigation from pond number 2 outlet to pond number 1 inlet to promote further oxidation. Pumping into the irrigation system from pond number 2 begins daily between 8 and 9 A.M. - and continues for a period of 16 to 18 hours depending on the early morning level of the pond, anticipated inflow, and precipitation. For optimum operation, the pond level is kept between 2.4 and 3.0 ft., with the most desirable level being 2.6 to 2.7 ft. The objective is to spray daily until about one-half of the wastewater present in the two ponds has been sprayed.

There are four major industrial waste sources in the area:

- **Cheese Factory:** The cheese factory waste probably has the greatest effect on the overall BOD input to the plant. Data obtained by the Kennedy Engineers, Incorporated for the City of Pleasanton indicate that the

Figure IV.A-1.
SCHEMATIC OF STUDY SITE


30 Meters Weather Tower
ALAMEDA COUNTY FAIRGROUNDS
BERNAL AVE
1000M
1600M
Sprayfield
Sprayfield
Sprayfield
Treatment Plant (Sunol)
Effluent Ponds
Pumping Station Location
Lake Manaco
West Lake Field
lower course
upper course
Castlewood Country Club
Valle
STANLEY
VINEYARD
Arroyo
Arroyo
Arroyo
b
d
OCATE STREET
ABRANT
54
56
58
Map of PLEASANTON CALIFORNIA

BOD level discharge waste from the cheese factory is approximately ten times that of normal domestic sewage. The cheese factory discharges approximately 0.016 MGD.

- Research Center: There is sizeable input (0.12 MGD) from the Kaiser Research Center, but available test data indicate it to be a waste of normal strength.
- Winery: The Villa Armondo Winery contributes the majority of its discharge (0.01 MGD) during the crushing season (fall and early winter). Data on this discharge have not been evaluated as of this date.
- Fair: The Alameda County Fair contributes a major portion of the industrial flow (0.25 MGD) during its month-long operation each summer. Available data indicate the possibility of high strength wastes.

2. Treatment Plant Process

The City of Pleasanton Sunol Sewage Treatment Plant (STP) utilizes physical and biological processes in the treatment of its sewage flow. This STP is unique in that it combines two biological waste treatment systems, fixed film and fluidized culture. The fixed film is conveniently termed "trickling filter" and the fluidized culture is termed "activated sludge". Additionally, the STP has aerated ponds which serve as polishing and equalization for the land application phase. Provisions have been made for odor control, such as lime addition, partial chlorination, and off-gas ozonation.

The biological treatment system, called contact biofiltration (CBF), appears to be a modification of a system described by Owen and Slechta in *Water and Sewage Works*, November 1975. The Sunol STP utilizes a variation of the combined trickling filter and activated sludge systems by using the system of contact stabilization. Figures IV. A-2 through IV. A-5 present the general plant layout flow scheme for liquid wastes and solids handling facilities.

The flow scheme proceeds as follows. After the raw influent passes through the chemical addition, pre-aeration, and primary sedimentation basins, the wastewater is combined with biological solids returned from the sludge aeration unit and biofiltration unit (trickling filter) recycled in the bio-filter sump to form a mixed liquor (similar to contact stabilization). This mixture (mixed liquor) is pumped from the bio-filter sump to the trickling filter, where it is distributed over a horizontal redwood slat filter media, reportedly creating an attached microorganism growth. The trickling filter underflow (effluent) proceeds to a second bio-filter sump where provisions exist for recycle of some portion of the flow back to the first bio-filter sump. The liquid that is not recycled proceeds to the secondary sedimentation basin where the biological solids are separated from treated wastewater. The biological solids are removed from the secondary sedimentation basins and some portions are wasted to the sludge digesters. The remaining sludge (biological solids) proceeds to the bio-unit sludge aeration tank where air is blown through the mixture. This stabilized sludge then proceeds to the first bio-unit sump, where it is mixed with fresh incoming clarified wastewater to undergo treatment in the trickling filter.

The liquid effluent from the secondary sedimentation basin is discharged to two aerated ponds in series. Water is pumped from the second pond to the spray irrigation fields.

3. Sunol STP Spray Effluent Quality

In general, the effluent quality as measured by Total Organic Carbon (TOC) and BOD values appeared to show significant seasonal variability. The average BOD and TOC concentrations during August-September 1975 were 35 and 48 mg/l, respectively, while during May-June 1976 the BOD average was 19 mg/l and the TOC was 33 mg/l. From October to December, 1976, the BOD values indicated effluent quality similar to the 1975 data, with monthly averages from 35 to 50 mg/l. After the first of the year, however, the effluent quality again improved, giving average BOD's from 19 to 24 mg/l.

The effluent quality as measured by organic parameters [TOC, COD (Chemical Oxygen Demand), BOD] and suspended solids appeared to improve during the Pre-Fair sampling period. The values showed slight declines during the first three weeks, then a marked decline from the third to the fourth week, and remained at this lowered level until the end of the sampling period.

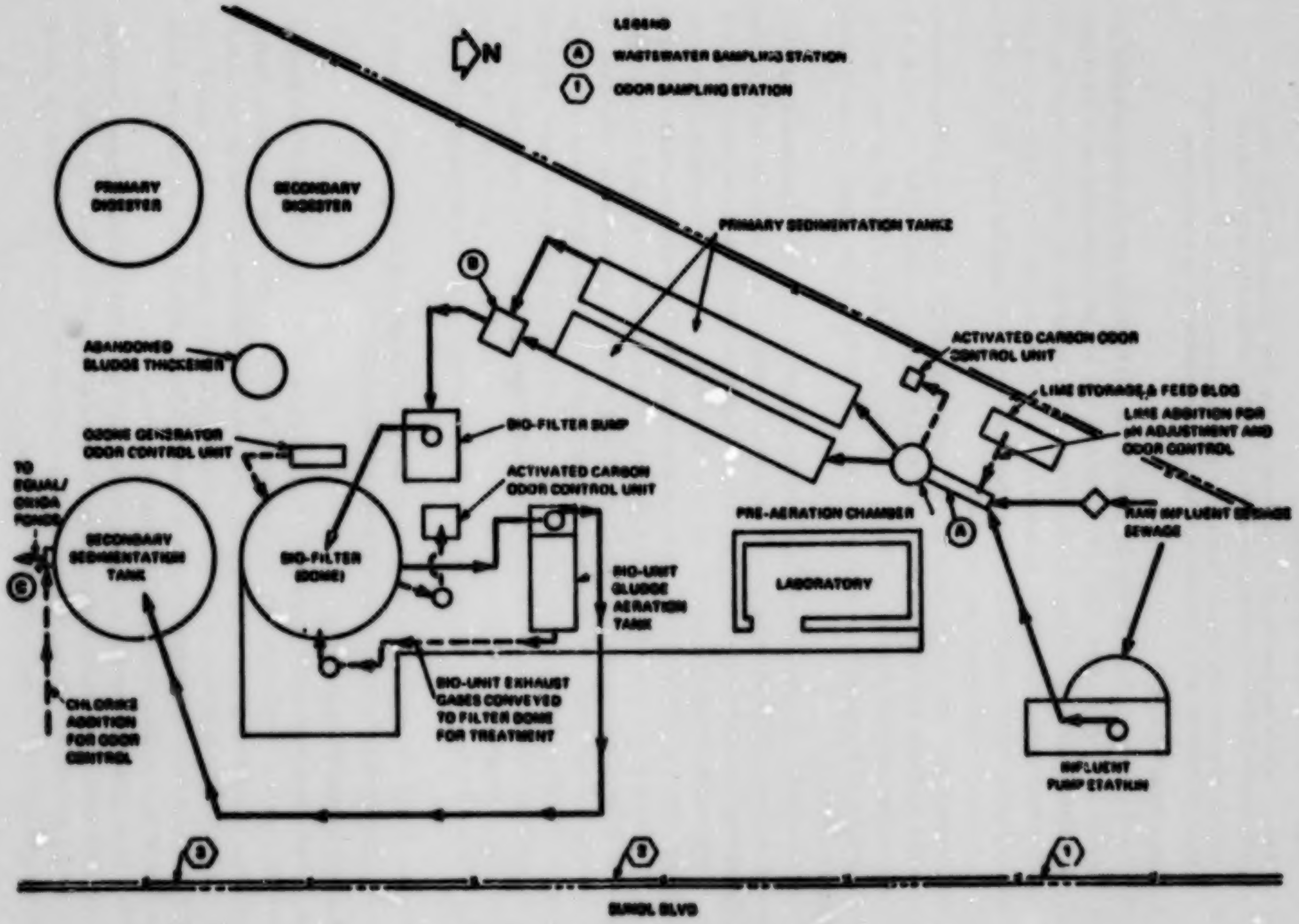

N
LEGEND
A WASTEWATER SAMPLING STATION
1 ODOR SAMPLING STATION
PRIMARY DIGESTER
SECONDARY DIGESTER
PRIMARY SEDIMENTATION TANKS
B
ABANDONED SLUDGE THICKENER
ACTIVATED CARBON ODOR CONTROL UNIT
LIME STORAGE & FEED BLDG
LIME ADDITION FOR pH ADJUSTMENT AND ODOR CONTROL
BIO-FILTER SUMP
OZONE GENERATOR ODOR CONTROL UNIT
ACTIVATED CARBON ODOR CONTROL UNIT
TO EQUAL/ OXIDA PONDS
C
SECONDARY SEDIMENTATION TANK
BIO-FILTER (DOME)
PRE-AERATION CHAMBER
A
RAW INFLUENT SEWAGE
BIO-UNIT SLUDGE AERATION TANK
LABORATORY
CHLORINE ADDITION FOR ODOR CONTROL
BIO-UNIT EXHAUST GASES CONVEYED TO FILTER DOME FOR TREATMENT
INFLUENT PUMP STATION
3
2
1
SUNOL BLVD

Figure IV.A-2.
PLANT LAYOUT AT PLEASANTON, CA

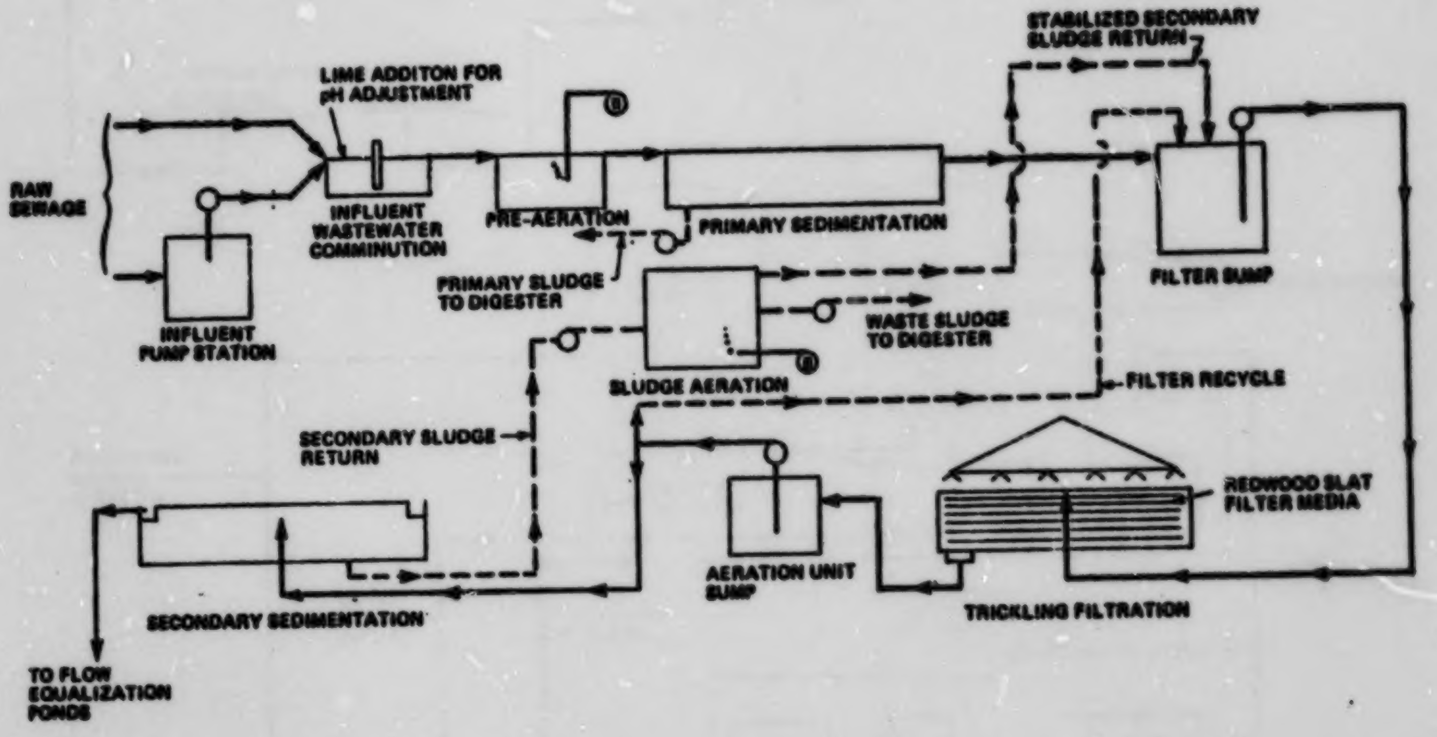

STABILIZED SECONDARY SLUDGE RETURN
LIME ADDITON FOR pH ADJUSTMENT
RAW SEWAGE
INFLUENT WASTEWATER COMMINUTION
PRE-AERATION
PRIMARY SEDIMENTATION
FILTER SUMP
PRIMARY SLUDGE TO DIGESTER
INFLUENT PUMP STATION
WASTE SLUDGE TO DIGESTER
SLUDGE AERATION
FILTER RECYCLE
SECONDARY SLUDGE RETURN
REDWOOD SLAT FILTER MEDIA
AERATION UNIT SUMP
SECONDARY SEDIMENTATION
TRICKLING FILTRATION
TO FLOW EQUALIZATION PONDS

Figure IV.A-3.
CONTACT BIO-FILTER PROCESS (CBF)

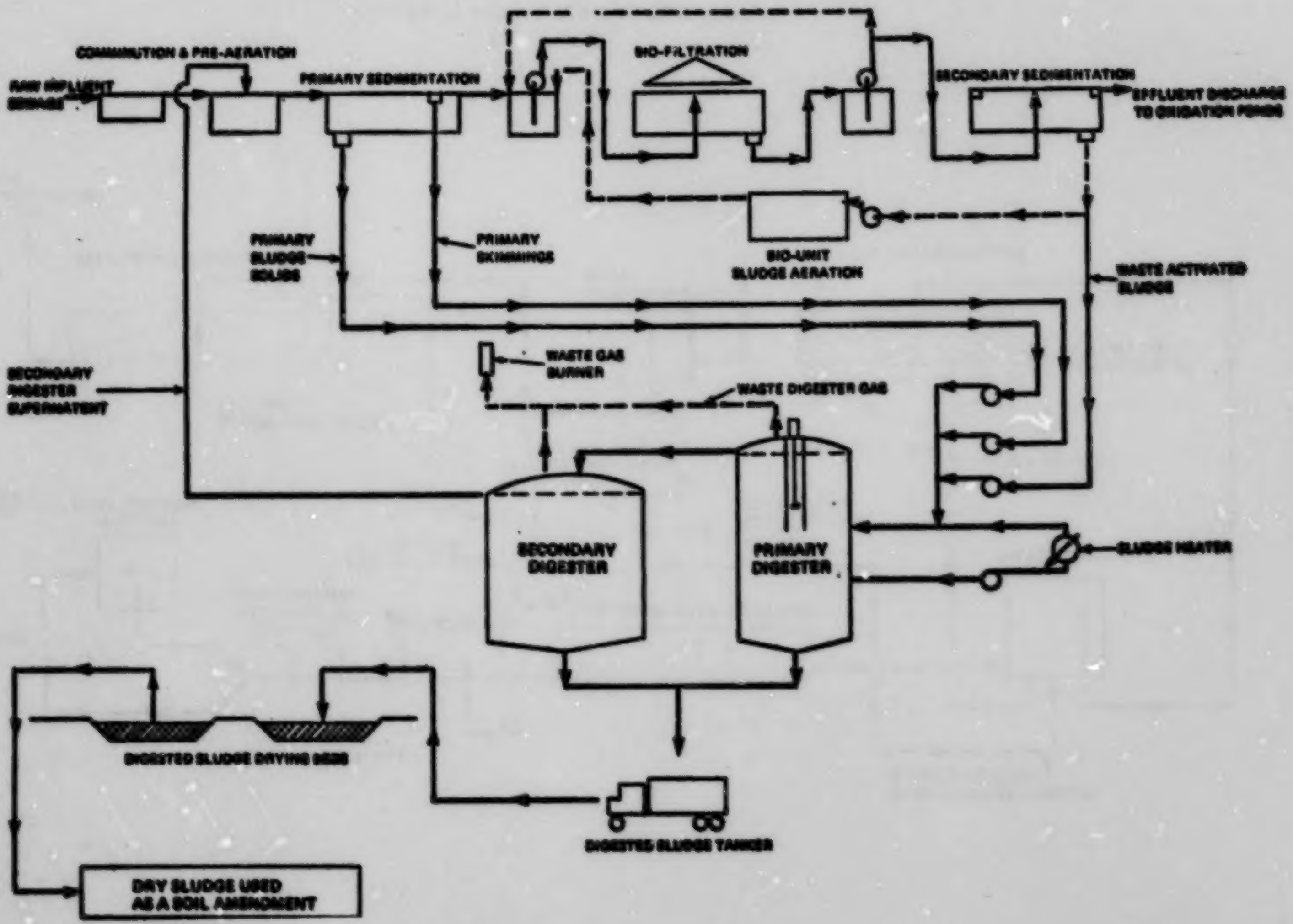

COMMINUTION & PRE-AERATION
RAW INFLUENT SEWAGE
PRIMARY SEDIMENTATION
BIO-FILTRATION
SECONDARY SEDIMENTATION
EFFLUENT DISCHARGE TO OXIDATION PONDS
PRIMARY SLUDGE SOLIDS
PRIMARY SKIMMINGS
BIO-UNIT SLUDGE AERATION
WASTE ACTIVATED SLUDGE
SECONDARY DIGESTER SUPERNATENT
WASTE GAS BURNER
WASTE DIGESTER GAS
SECONDARY DIGESTER
PRIMARY DIGESTER
SLUDGE HEATER
DIGESTED SLUDGE DRYING BEDS
DIGESTED SLUDGE TANKER
DRY SLUDGE USED AS A SOIL AMENDMENT

Figure IV.A-4.
SOLIDS HANDLING FACILITIES

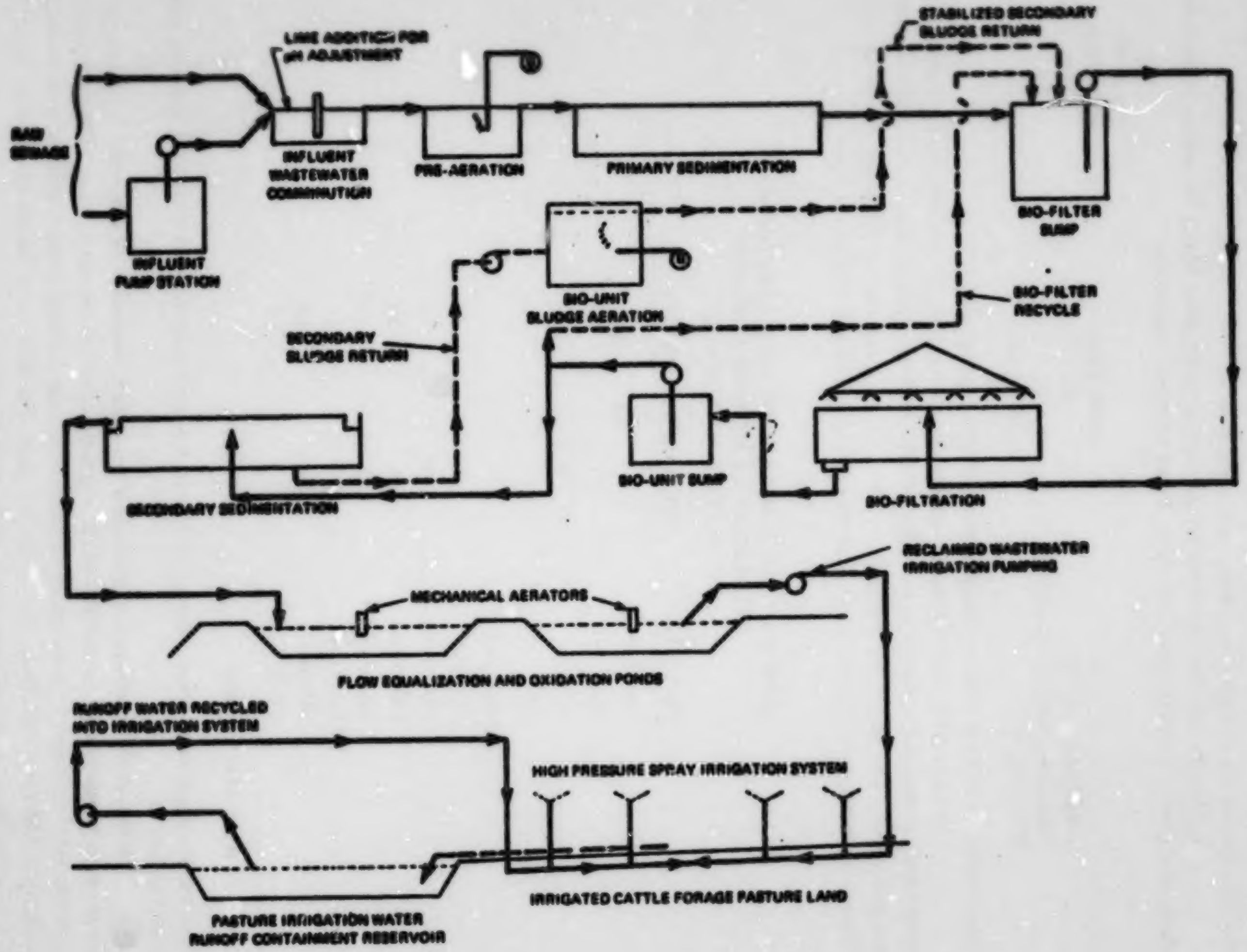

RAW SEWAGE
INFLUENT PUMP STATION
LIME ADDITION FOR pH ADJUSTMENT
INFLUENT WASTEWATER COMMINUTION
PRE-AERATION
PRIMARY SEDIMENTATION
STABILIZED SECONDARY SLUDGE RETURN
BIO-FILTER SUMP
BIO-UNIT SLUDGE AERATION
BIO-FILTER RECYCLE
SECONDARY SLUDGE RETURN
BIO-UNIT SUMP
BIO-FILTRATION
SECONDARY SEDIMENTATION
RECLAIMED WASTEWATER IRRIGATION PUMPING
MECHANICAL AERATORS
FLOW EQUALIZATION AND OXIDATION PONDS
RUNOFF WATER RECYCLED INTO IRRIGATION SYSTEM
HIGH PRESSURE SPRAY IRRIGATION SYSTEM
IRRIGATED CATTLE FORAGE PASTURE LAND
PASTURE IRRIGATION WATER RUNOFF CONTAINMENT RESERVOIR

Figure IV.A-5.
PLANT AND DISPOSAL FACILITY FLOW SCHEMATIC

The weekly average values for BOD (during Pre-Fair) met the standard for secondary treatment as defined by EPA (30mg/l BOD), but exceeded the standard in the October through December, 1976 period. After this time, the levels decreased to be consistent with EPA guidelines. During the period of the fourth week until the seventh week of the Pre-Fair, the weekly average values for total suspended solids (TSS) also met the standard for secondary treatment of 30 mg/l TSS.

During the Pre-Fair sampling period, one sampling date, May 27th, coincided with sampling of the aerated pond effluent by plant operators. A comparison is made below:

	SwRI Data	Sunol STP Plant Data
Total Solids (mg/l)	618	631
Total Suspended Solids (mg/l)	12	15
BOD (mg/l)	11(May 28)	10

These values for BOD and TSS represent reasonably good quality effluent.

The Sunol STP plant operators sampled the effluent from the secondary sedimentation tanks. This sampling point does not represent overall plant effluent but represents influent to an additional treatment step -aerated ponds. The values for May, June, and July are presented in Appendix A, along with October through April analyses. A summary of these results is presented in the following table.

TABLE IV. A-1. SUMMARY OF SUNOL SECONDARY EFFLUENT PARAMETER ANALYSIS MONTHLY AVERAGE

Month/Year	BOD_5 (mg/l)	TSS (mg/l)	COD (mg/l)
Pre-Fair			
May, 1976	27	15	93
June	29	40	--
July	26	42	--
Post-Fair			
October	34	24	--
November	>34*	24	--
December	48	36	--
January, 1977	42	--	100
February	27	15	--
March	21	18	--
April	22	15	--

---

*one value reported as 54 mg/l.

These values suggest that some removal of organic material (suspended or dissolved) is taking place in the aerated ponds.

A listing of operational modifications by date is presented in Appendix B. These operational changes were primarily made as controls of the suspended solids in the mixed liquor. The addition of digester solids was made to increase the mixed liquor suspended solids (MLSS) concentration in order to maintain approximately 3,000 mg/l MLSS applied to the bio-filter. The wastage of the return activated solids (RAS) to the primary sedimentation tanks was made for the same purpose.

B. Spray Irrigation Operations

The spray equipment is designed so that a volume of water equal to the amount of incoming raw sewage, less evaporation losses, is sprayed onto cattle pastures daily. This is attained by keeping the level in the final effluent pond No. 2 (see Figure IV. B-1) receiving the secondary effluent as constant as possible by pumping more or less water to the irrigation fields. This is accomplished by adjusting the daily irrigation time from 12 to 18 hours. Two pumps, 100- and 75-HP, respectively, with a third standby pump, are used to move the water through 10-in. mains to the fields.

Table IV. B-1 lists the daily incoming raw sewage volumes versus the volume sprayed for the months of May and June, 1976. The volume of wastewater sprayed daily is estimated from the water levels in ponds 1 and 2.

TABLE IV. B-1 PLANT FLOW DATA
(thousands of gallons)

	MONTH			
	MAY		JUNE	
DAY	INFLOW	OUTFLOW	INFLOW	OUTFLOW
1	1,310	1,873	1,371	1,486
2	1,293	1,981	1,386	1,466
3	1,301	1,878	1,366	1,300
4	1,398	1,410	1,400	1,183
5	1,310	1,398	1,183	1,368
6	1,298	1,676	1,384	1,476
7	1,296	1,657	1,406	1,406
8	1,377	1,756	1,476	1,580
9	1,276	1,741	1,480	1,317
10	1,261	2,137	1,417	1,502
11	1,357	1,911	1,482	1,400
12	1,331	1,028	1,046	1,390
13	1,328	1,410	1,400	1,356
14	1,310	1,357	1,390	1,476
15	1,357	1,291	1,376	1,432
16	1,291	1,791	1,332	1,108
17	1,291	1,600	1,408	1,426
18	1,400	1,016	1,326	1,392
19	1,316	1,103	1,342	1,332
20	1,403	1,206	1,332	1,331
21	1,306	1,465	1,331	1,620
22	1,365	1,568	1,520	1,252
23	1,368	1,494	1,452	1,433
24	1,394	1,335	1,333	1,282
25	1,535	1,491	1,382	1,475
26	1,391	1,232	1,475	1,172
27	1,332	1,457	1,372	1,611
28	1,357	1,884	1,361	1,594
29	1,384	1,256	1,494	2,001
30	1,256	1,076	1,501	1,008
31	1,176	1,076		
TOTAL:	41,368	46,554	41,734	42,273
AVG.:	1,334	1,502	1,391	1,409

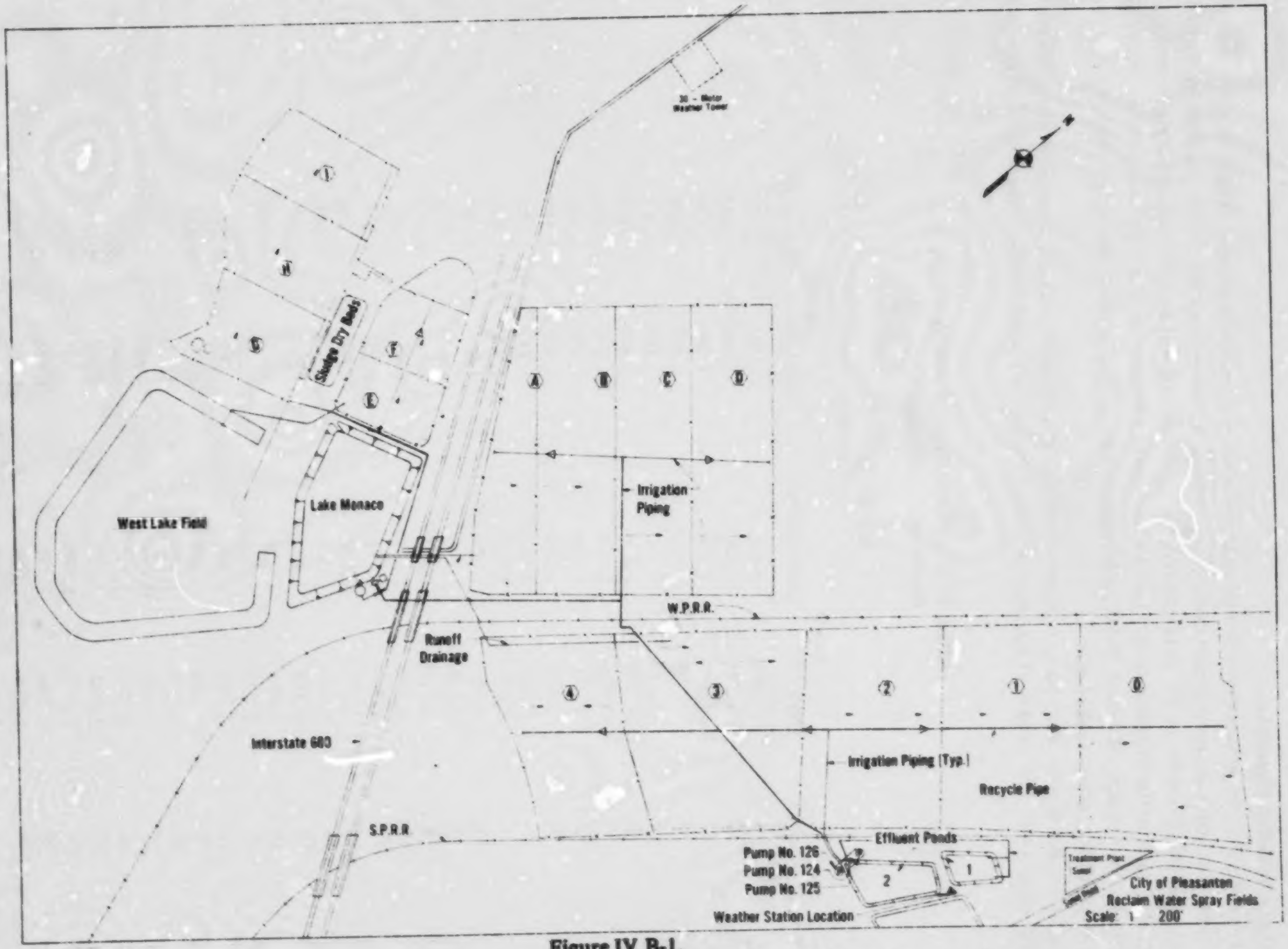

30 - Meter Weather Tower
Sludge Dry Beds
West Lake Field
Lake Monaco
Irrigation Piping
W.P.R.R.
Runoff Drainage
Interstate 680
S.P.R.R.
Irrigation Piping (Typ.)
Recycle Pipe
Effluent Ponds
Pump No. 126
Pump No. 124
Pump No. 125
Weather Station Location
Treatment Plant Site
City of Pleasanton
Reclaim Water Spray Fields
Scale: 1" = 200'

Figure IV.B-1.
SPRAY PATTERN FOR FIELDS DURING PRE-FAIR STUDY

Two major parcels and one smaller parcel of land are subdivided into smaller fields for the purposes of cattle management. The two larger areas are a 62-acre field labeled A,B,C, and D and a 100-acre field labeled 0,1,2, 3, and 4. The smaller fields across Interstate 680 are labeled E,F,G,H, and I.

The water is applied to these fields through Rainbird® No. 30 sprinkler heads which have been drilled to have 7/32- and 11/64-in. orifices. The spray heads , on 2-ft. high risers of 1-in. iron pipe, are connected to 3-in. aluminum irrigation pipes. The sprayers are located every 30 ft. along the irrigation pipe. Each spray wets an area approximately 18 meters in diameter and reaches a maximum height of approximately 5 meters.

The transit time of the water in the pipes ranges from 4 minutes, 40 seconds to the center sprays in field 3 to 24 minutes, 40 seconds to the furthermost sprays in field D. These transit times were measured by observing the appearance of dye at the sprays after its introduction at the pumps. Transit time to the fields across the Interstate was not measured, since no aerosol sampling was planned for that area.

The rate of application of water from individual sprayers depended primarily on their location along a line of sprayers. Measured rates ranged from a high of 86 l/min at individual sprayers next to the main water line (usually in the center of the line of sprayers) to a low of 30 l/min for the sprayers at the ends of sprayer line. These rates varied depending on the field and number of sprayers used.

As an example, Table IV. B-2 presents the flow measurements made in field B at every other spray starting from the northwest side of the field. These flows were determined by measuring the time required to fill a 20-l container directly from the individual spray heads. The entire flow from both nozzles on each sprayer was directed into a measuring container by two short lengths of tubing slip-sealed over the nozzles. The time required to fill the 20-l container was measured using a standard stopwatch.

TABLE IV. B-2. SPRAY VOLUME—FIELD B
(Every other Spray, Second Day Setting)

Spray Head No.	Liter/Minute Flow
1	35.3
3	35.8
5	36.7
7	40.5
9	39.9
11	42.9
13	43.6
15	46.2
17	50.0
19	53.6
21	51.1
23	69.8
25	74.1
Main irrigation supply line	
27	78.9
29	63.5
31	32.3
33	44.1
35	53.1
37	46.0
39	45.3
41	42.1
43	39.9
45	39.2
47	31.0
49	38.7
51	42.0

Effluent is simultaneously sprayed onto one field in each of three parcels of land (i.e., three separate fields) every day of the year. The dashed lines in Figure IV. B-1 represent the first position the spray lines would be in for each field if irrigation was scheduled for that particular field. Note that some fields have more than one spray line. The number of days each field is irrigated and the number of sprayers used is indicated in Table IV.B-3. It should also be noted that some fence lines were changed between Pre- and Post-Fair sampling periods.

TABLE IV.B-3. CHARACTERISTICS OF PRE-FAIR SPRAY FIELDS

Field No. or Letter	No. of Days Irrigated	No. of Spray Heads
0	7	70-90
1	6	66-69
2	6	68
3	4	59-69
4	5	70
A	7	35-51
B	7	51-53
C	7	52
D	7	52
E	6	13-17
F	7	17
G	8	18
H	8	18-19
I	7	19

The number of days irrigated and the number of sprayers used depends on the size, shape, and contour of the field being irrigated. The normal sequence of irrigation begins with fields 4, A, and E, with the spray lines being moved 60 ft. daily in the direction of the arrows as shown in Figure IV. B-1. Once any field (4, A, or E) has been irrigated, the spray lines are moved to the first position of the next field to be irrigated (i.e., 3, B, or F). This sequence is continued daily, always keeping the cattle in the dry field just ahead of the irrigation.

Runoff from the spray fields drains through steel pipe to a holding pond (Lake Monaco) located southwest of Interstate 680 (Figure IV. B-1). This pond, as well as West Lake Field, is used for additional holding capacity. This additional capacity is needed during rainy periods and as a reservoir for holding of effluent if problems occur with the spray operations. The plant may also irrigate from Lake Monaco when necessary.

C. On-Site Facilities

On-site facilities consisted of a large storage area and a mobile office trailer with laboratory space. The storage building was used as an assembly area for the maintenance and storage of all portable field equipment. The laboratory space in the mobile office trailer was utilized for sample preparation and on-site analysis. Various equipment in the laboratory essential to the operation of the Pre-Fair and Post-Fair studies are in Appendix D.

D. General Meteorological Conditions

1. Pre-Fair

May and June, 1976, were, from a meteorological standpoint, abnormally warm and dry in the general area of the sampling site and, indeed, in most of California. The period was marked by a persistent surface high pressure area centered in the Pacific Ocean well off the West Coast of the United States. This high pressure extended over California.

Aloft at 500 mb (about 18,000 ft), a low pressure area persisted over or in the vicinity of the Gulf of Alaska. Occasionally, this low pressure area would elongate generally north-south in the Pacific Coast area.

These synoptic features resulted in weak maritime cold fronts moving southeastward from the vicinity of the Gulf of Alaska and the area immediately to the south of the Gulf down over the Pacific Coast at intervals ranging from every one to three days. The weaker cool outbreaks tended to move primarily across the northern tier of states, with their western extremities moving through or close to the sampling site with an east-west orientation. Such fronts tended to dissipate in the general area of the sampling site. The stronger cool outbreaks tended to continue moving southeastward across the Rockies to the central United States. The accompanying western extension of the frontal zones moved through the sampling site with a northeast-southwest orientation. However, as the cool push continued into Utah, Arizona, and New Mexico, the trailing or western extremity of the front tended to pass through the sampling site and then stagnate with a north-south orientation paralleling the coastal hill ranges. This situation resulted in a temporary trough of low pressure lying near the sampling site, or moving eastward across the site and then regressing to the west.

Precipitation with the frontal passages was mainly confined to the states north of California. Very seldom during May and June did precipitation reach California and, when it did, it was generally confined to extreme coastal northern California.

The windrose pattern (percentage of time wind blows from a certain direction at several ranges of velocity) measured for the period of May and June, 1976 is presented in Figure IV. D-1. This pattern is significantly different than that measured for August and September, 1975. Calm winds were prevalent 20% of the time during the later period versus 70% of the time during August and September, 1975.

2. Post-Fair

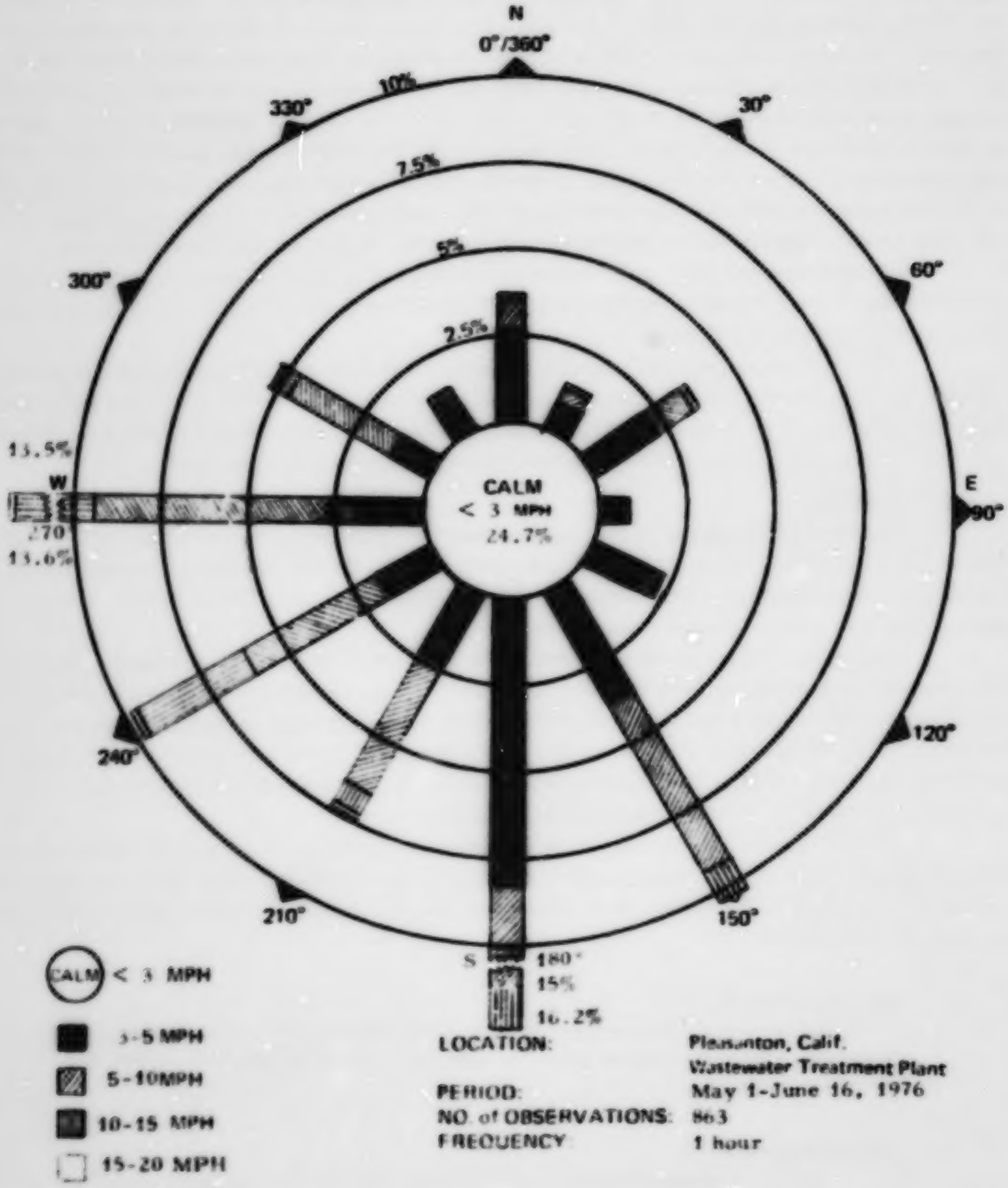
The period of December 1976 through January 1977 was marked by a persistent surface high pressure area centered over the Great Basin to the east of Pleasanton. The 500-mb flow was predominantly from the northwest influenced by a quasi-permanent ridge just off the west coast. The result was a generally weak surface wind flow at the site from the east quadrant.

The period of February through April, 1976, for the most part, came under the influence of a surface high pressure area centered over the Pacific Ocean well off the west coast of the United States. This pressure system extended its influence over California and brought surface winds to the Pleasanton area from the northwest and north quadrants. The flow at 500 mb was also generally from the northwest, with ridging persisting over the Pacific Ocean. There were brief interludes of frontal passages during this period which were preceded by surface winds from the southwest in the Pleasanton area.

A set of synoptic weather maps is presented in Appendix C, in order to better depict the various synoptic regimes which occurred during each of the sampling trials conducted during the period of December 1976 through April 1977. The surface winds observed during this period were characterized by three distinct synoptic regimes as follows:

> *Synoptic Regime No. 1*
> A high pressure cell is centered over the Great Basin to the east or northeast of Pleasanton. The mean surface wind direction observed during the trial periods was from the east quadrant.
>
> *Synoptic Regime No. 2*
> A cold front approaches the Pleasanton area from the west or northwest. The mean surface wind direction observed was from the south quadrant.

Figure IV.D-1.
PRECENT DISTRIBUTION OF WIND DIRECTIONS AND WIND SPEEDS



LOCATION:	Pleasanton, Calif. Wastewater Treatment Plant
PERIOD:	May 1-June 16, 1976
NO. of OBSERVATIONS:	863
FREQUENCY:	1 hour

Synoptic Regime No. 3

A post-frontal high pressure system lies to the west or northwest of Pleasanton. The mean surface wind direction observed during the trial periods was from the northwest and north quadrants.

During the period of testing, the surface winds over the site were generally light. Under this situation, the wind direction was quite variable because of the influence of local topography. Pleasanton is situated in a valley bounded on the near west by a low range of hills. Another range of hills lies to the southeast and is oriented northeast-southwest. The south opening of the valley leads to San Jose, and the terrain to the north slopes gradually upward. Thus, when the surface winds are light, there is an ill-defined flow generally from a northwesterly direction or its reciprocal broken by a sporadic flow from the northeast or southwest. A well-organized flow from the southeast occurs when a front is approaching and becomes northwesterly after the frontal passage.

The orientation of the spray line (northwest-southeast) is such that when the flow is well organized it parallels the spray line. Conversely, under light wind conditions the surface wind direction is variable, and the flow perpendicular to the spray line occurs only intermittently.

V. Methods and Materials

Note to Reader: Complete documentation of the methods and materials is necessary to establish the credibility of this study's results and to serve as a guide to future investigators. Inclusion of this lengthy section in the body of the report, however, hampered readability and was not necessary to permit reader comprehension of the study's findings. Thus, the complete Materials and Methods section has been included as Appendix D. The following synopsis of that section is provided to indicate what procedures, measurements and evaluations were performed and their reason for inclusion in this research effort. Appendix D follows the same outline format as this section to aid the reader requiring greater detail.

A. Sample Collection and Handling Methods

1. Meteorological Measurements and Instrumentations

On-site meteorological measurements were required to: 1) permit appropriate placement of the aerosol sampling equipment and (2) provide necessary input to the microbiological dispersion model. Measurements made during the study period included: wind velocity and direction, temperature, relative humidity, precipitation, and solar radiation. In addition, estimates of the atmospheric stability category during each aerosol run were made using meteorological data and observations to provide additional input to the microbiologial dispersion model. A site map giving meteorological measurement locations is presented in Figure V. A-1.

2. Wastewater Sampling Methods

A wastewater sampling and analysis program was conducted to document the quality of effluent during the study period and explore the possible relationships between effluent quality and aerosol concentrations.

a. *Daily Composite Samples*

During Pre-Fair studies only, daily composite effluent samples were collected from the wastewater being pumped from pond 2 to the spray fields. These samples underwent analysis for pH, chlorine (free and total), total organic carbon, solids (suspended and total), nitrogen series (nitrate, nitrite, ammonia, and organic nitrogen), phosphorus, BOD, COD, hardness and microbiological analyses.

b. *Grab Samples*

Three types of wastewater grab samples were collected during the study period.

1. Pond-chlorine. A single 500 mL grab sample was collected daily near the pond 2 pumping station for analyses of free and total chlorine (Pre-Fair only).

2. Pond-pathogen screen. A number of 20-liter large-volume grab (LVG) samples were collected from pond 2, in the vicinity of the spray field pumps, for detailed microbiological characterization. This permitted identification of prevalent pathogens in the effluent as candidates for later more routine analyses.

3. Spray line. To permit direct comparisons between effluent quality and aerosol concentration levels, wastewater samples were collected at the spray line during each aerosol sampling run.

3. Aerosol Sampling Methods

a. *High-volume Samplers For Microorganism Aerosols*

A total of 16-18 high-volume aerosol samplers were available during the study and usually

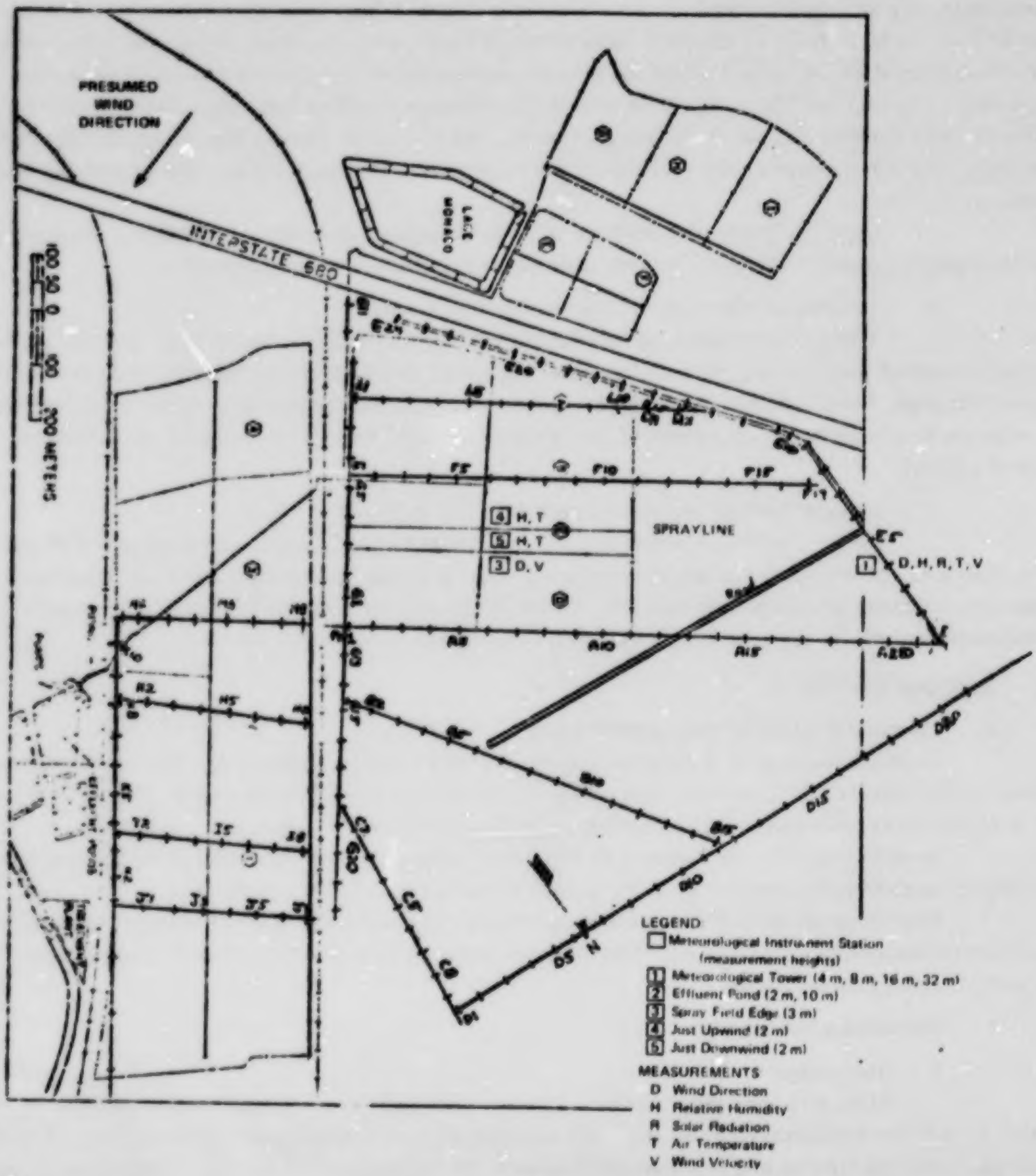

PRESUMED WIND DIRECTION
INTERSTATE 680
LAKE MORAGA
100 50 0 100 200 METERS
SPRAYLINE
4 H, T
5 H, T
3 D, V
1 D, H, R, T, V
N
LEGEND
Meteorological Instrument Station (measurement heights)
1 Meteorological Tower (4 m, 8 m, 16 m, 32 m)
2 Effluent Pond (2 m, 10 m)
3 Spray Field Edge (3 m)
4 Just Upwind (2 m)
5 Just Downwind (2 m)
MEASUREMENTS
D Wind Direction
H Relative Humidity
R Solar Radiation
T Air Temperature
V Wind Velocity

Figure V.A-1.
SITE MAP WITH ENVIRONMENTAL MEASUREMENT LOCATIONS

about eight were used simultaneously in most microbiological sampling efforts. Several were LEAP samplers, Model 3440, manufactured by Environmental Research Corporation, St. Paul, Minnesota. Most samplers were the Litton Model M Large-Volume Air Sampler, manufactured by Applied Science Division, Litton Systems, Inc., Minneapolis, Minnesota. Both samplers are designed to collect airborne particles by electrostatic attraction to a rotating disk on which they are concentrated into a thin, moving film of liquid. The nominal sampling rate of both instruments is 1000 liters per minute. Nominal sampling time per aerosol run was 30 minutes.

Appendix D provides extensive detail on description of samplers, selection of the liquid collection medium, sampler calibration, sampler disinfection procedures and sample handling.

b. All Glass Impinger (AGI) Samplers For Dye Aerosols

A 20-percent solution of Rhodamine WT dye was injected into the spray line and resultant aerosols sampled using 50-mL graduated all-glass impingers manufactured by Scientific Glass and Instruments, Houston, Texas. The purpose of these dye aerosol runs, conducted during a variety of meteorological conditions, was to determine the percent of the sprayed wastewater that leaves the site as aerosol (aerosolization efficiency).

c. Rotorod Samplers For Fluorescent Particle (FP) Tracer

During Post-Fair microbiological aerosol sampling runs, a fluorescent particle (FP) aerosol was generated near the spray line and sampled downwind, as a quasi-quantitative tracer, to document wind (and, consequently, aerosol plume) direction. A total of 40 rotorod samplers (Barber Colman type BYQM 2020) were available for sampling FP aerosols, and about 20 were used during each run.

B. Analytical Methods

1. Chemical Analysis of Wastewater Samples

Chemical analyses of wastewater samples fell under two categories, "routine" and "selective", based on the frequency these analyses were conducted during both Pre-Fair study periods. Tables V. B-1 and V. B-2 identify the parameters measured and reference the method used during both study periods.

In order to justify the shipment of TOC water samples to SwRI laboratories in San Antonio for subsequent analysis (maximum 14 days holding time) a holding time study was performed.

Fluorescent particles (FP), collected on rotorod samples during Post-Fair aerosol sampling, were analyzed microscopically. The rotorod FP samples were analyzed by comparison to six standard samples provided by Dugway Proving Grounds.

2. Microbiological Analyses

a. Wastewater

Most microbiological analyses of wastewater samples were conducted on a routine basis. Table V. B-3 lists the microorganisms that were routinely assayed from daily composite of spray line grab samples during the Pre-Fair and Post-Fair study periods. The enumeration of these microorganisms in wastewater samples provided a basis for evaluating their survival when aerosolized.

Most large-volume grab wastewater samples, collected from pond 2 primarily during Pre-Fair, underwent analysis for the 20 microbial types listed in Table V. B-4. This pathogen screen was intended to identify prevalent microorganisms in the effluent as improved candidates for routine analysis during later study periods. One large-volume sample was frozen prior to shipping and analyzed for respiratory viruses (adenoviruses, mumps virus, REO viruses, herpesviruses, cytomegalovirus, and measles virus).

b. Aerosols

Aerosol samples were submitted for analysis of the same microorganisms identified for wast-

Table V.B-1
ANALYTICAL METHODS FOR PRE-FAIR WASTEWATER CHEMICAL ANALYSES

Analysis	Analytical Laboratory*	Method		Detection Limit	Remarks
		Ref†	Page	mg/L	
Routine Parameters					
pH	SwRI-PL	1	276	NA	Glass electrode and Fischer Accumet pH meter.
Free chlorine	SwRI-PL	3		0.05	FACTS method. Optimal density determined by Hach DR-EL/2.
Total chlorine	SwRI-PL	1	129	0.1	DPD ferrous colormetric method. Optical density determined by Hach DR-EL/2.
Total Suspended Solids (TSS)	PEL	2	268	10	Gooch crucible with glass fiber filtration and dryness at 103 to 105°C.
Total Solids	PEL	2	270	10	Evaporation at 103 to 105°C.
Total Organic Carbon (TOC)	SwRI-SA	2	237	1	Analysis performed with a modified Beckman Carbon Analyzer after acidification and N_2 stripping.
Selective Parameters					
Chemical Oxygen Demand (COD-total)	SwRI-SA	1	495	2	Dichromate reflux followed by ferrous ammonium sulfate titration.
Biochemical Oxygen Demand (BOD)	PEL	1	489	1	5-day incubation at 20°C. Weston and Stack D.O. probe.
Total Phosphorus	SwRI-SA	1	523	0.1	Persulfate digestion, stannous chloride color development.
Nitrate Nitrogen (NO_3—N)	SwRI-SA	1	461	0.1	Brucine method.
Nitrate Nitrogen (NO_2—N)	PEL	2	215	0.01	Diazo dyemethod.
Ammonia Nitrogen (HH_3—N)	SwRI-SA	1	222,244	0.1	Distillation followed by Nesslerization.
Organic Nitrogen (Organic N)	SwRI-SA	1	244	0.1	Determined on residue from ammonia distillation. Digestion, distillation and Nesslerization.
Total Hardness ($CaCO_3$)	SwRI-PL	1	179	5	EDTA Titration.

* Analytical laboratories were:

SwRI-SA - Southwest Research Institute, San Antonio laboratories
SwRI-PL - Southwest Research Institute, Pleasanton, California facility
PEL - Pacific Environmental Laboratory, San Francisco, California

† References and footnotes for analytical tests were:

(1) AWWA, APHA, WPCF, *Standard Methods for the Examination of Water and Wastewater*, Thirteenth edition, American Public Health Association, Washington, D.C. 1971.
(2) *Methods for chemical Analysis of Water and Wastes*, U. S. Environmental Protection Agency, Washington, D.C. 1974.
(3) Cooper, W.J., Sorber, C.A. and Meier, E.P., "A Rapid Specific Free Available Chlorine Test with Syringaldazine (FACTS), *Journal of American Water Works Association*, 67 (1), 34-39, January 1975.

Table V. B-2

ANALYTICAL METHODS FOR POST-FAIR WASTEWATER CHEMICAL ANALYSES

Analysis	Analytical Laboratory[*]	Method Ref[†]	Method Page	Detection Limit mg/L	Remarks
Routine Parameters					
pH	SwRI-PL	1	460	NA	Glass electrode and Fischer Accumet pH meter.
Total Organic Carbon (TOC)	UTSA	2	237	2	Samples acidified upon collection. N_2 stripped before analysis. Beckman Model 915A with Model 865 Infrared Analyzer.
	SwRI-HOU				Modified Beckman Model315 with Model 865 Infrared Analyzer.
Total Suspended Solids (TSS)	UTSA	1	94	10	Glass fiber filtration and dryness at 103 to 105°C.
Conductivity	SwRI-PL	1	71	5 mho/cm	Hach DR-EL/2 conductivity probe.
Selective Parameters					
Chemical Oxygen Demand (COD)	PEL	1	550	2	Dichromate reflux followed by ferrous ammonium sulfate titration.
Nitrate Nitrogen (NO_3—N)	PEL	1	427	0.1	Brucine method
Ammonia Nitrogen (NH_3—N)	PEL	1	417	0.1	Distillation followed by titration with standard acid.
Organic Nitrogen	PEL	1	437	0.1	Determined on residue from ammonia distillation. Digestion, distillation and titration with standard acid.
Nitrate Nitrogen (NO_2—N)	PEL	2	215	0.01	Diazo dye method.
Total Phosphorus (Total) P	PEL	1	473	0.1	Persulfate digestion, stannous chloride color development.
Total Solids	PEL	1	91	10	Evaporation at 103 to 105°C.
Biochemical Oxygen Demand (BOD_5)	PEL	1	543	1	5-day incubation at 20°C. Weston & Stack D.O. Probe.

[*] Analytical laboratories were:

SwRI-SA - Southwest Research Institute, San Antonio laboratories
SwRI-PL - Southwest Research Institute, Pleasanton, California facility
PEL - Pacific Environmental Laboratory, San Francisco, California

[†] References and footnotes for analytical tests were:

(1) AWWA, APHA, WPCF, *Standard Methods for the Examination of Water and Wastewater*, Thirteenth edition, American Public Health Association, Washington, D.C. 1971.

(2) *Methods for chemical Analysis of Water and Wastes*, U. S. Environmental Protection Agency, Washington, D.C. 1974.

Table V.B-3
MICROORGANISMS ROUTINELY ASSAYED IN WASTEWATER

Microorganism	Pre-Fair	Post-Fair
Standard bacterial plate count	D,R	R
Total coliform	D,R	R
Fecal coliform	D,R	
Coliphage	D,R	R
Fecal streptococci	D	R
Pseudomonas	D	
Klebsiella	D	
Clostridium perfringens	D	
Mycobacteria		R
Enteroviruses-3 day count	D	
Enteroviruses-5 day count	D	

D—daily composite sample
R—spray line grab sample with each aerosol run

Table V.B-4
MICROBIAL TYPES SOUGHT IN PATHOGEN SCREEN

Quantitative:
- *Klebsiella*
- *Pseudomonas*
- *Clostridium perfringens*
- Fecal Streptococci

Semi-quantitative:
- *Staphylococcus aureus*
- Mycobacteria
- *Leptospira*
- *Shigella*
- *Salmonella* (including Arizona)
- *Enterobacter*
- *Serratia*
- *Edwardsiella*
- *Escherichia*
- *Citrobacter*
- *Proteus*
- *Providencia*
- *Yersinia*
- *Neisseria* (pathogenic)
- *Aeromonas* and other oxidase-positive fermenters

ewater samples (10 assays on Pre-Fair samples, 5 assays on Post-Fair samples). Comparison of the wastewater and aerosol concentration data permitted evaluaton of the survival properties of each microbial type. This included survival during the aerosolization process and, by comparion of concentration data at various downwind locations, long-term survival while in the aerosol state.

Several of the specific assay methods were different from those used for wastewater samples. This was largely due to the smaller volume of aerosol collection fluid available for assay.

C. Quality Assurance

A major goal of this research was to determine if wastewater measurements could be used as a basis for predicting the microbiological quality of aerosols from spray irrigation sites. This necessitated a definition of the accuracy and precision of all methods used. To accomplish this a quality assurance program was established which had two primary objectives:

(1) To determine the accuracy and precision of laboratory analyses, and

(2) To determine if there were systematic differences in high-volume aerosol sampler collection efficiency.

Quality assurance tasks for wastewater analyses included the use of spiked reference samples, the comparison of replicate samples sent to more than one laboratory and the comparison of replicate samples sent to a single laboratory. Quality assurance aerosol runs were conducted by placing all samplers at the same distance from the spray line on approximately one meter centers. Analyses of the sampler collection fluid were performed by several laboratories in a manner that permitted relative comparion of between samplers and within-sampler precision.

D. Aerosol Sampling Protocols

1. Microbiological Aerosol Runs

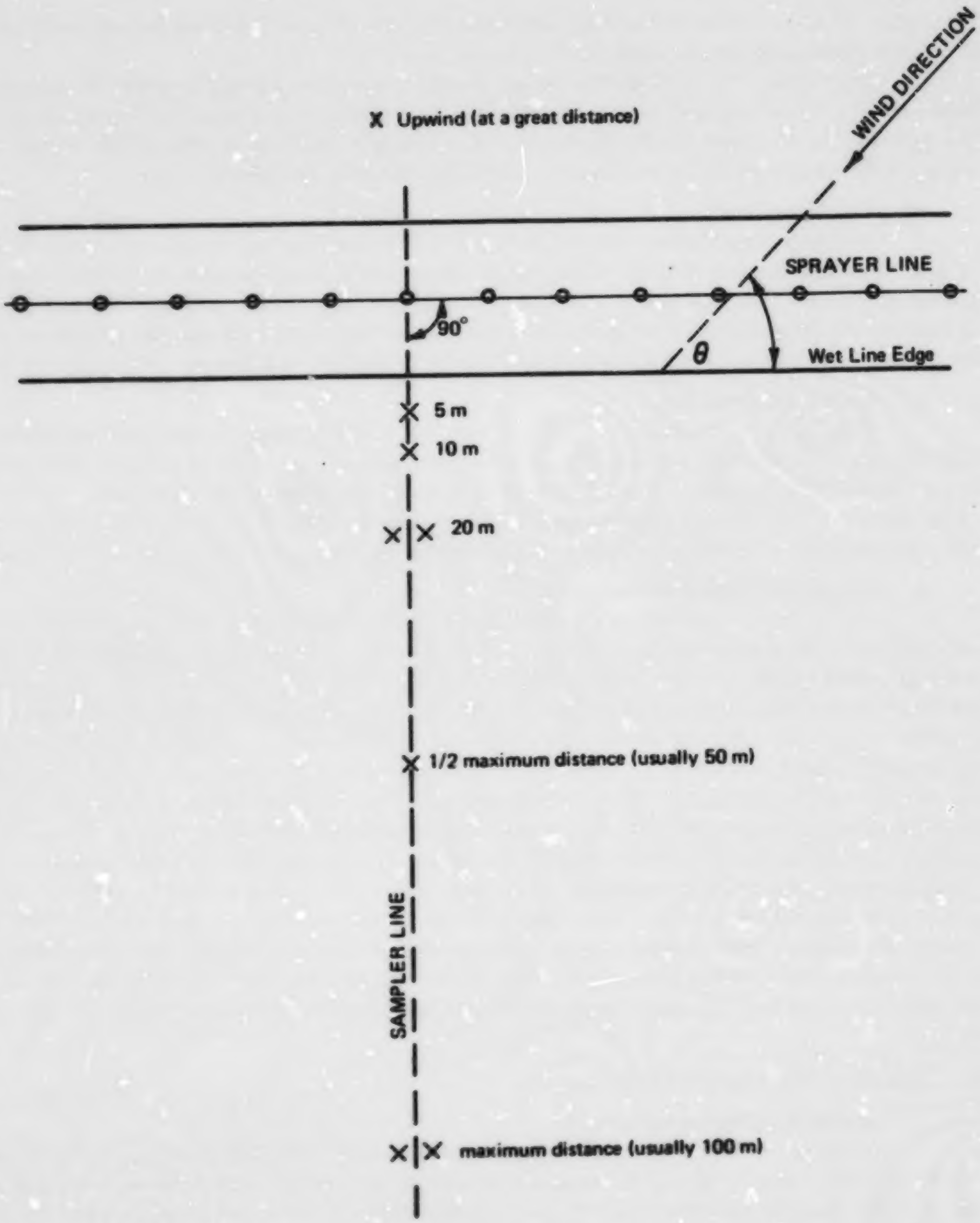
Eight (when available) high-volume aerosol samplers were utilized during each aerosol sampling run. One was located well upwind to provide a measure of aerosol background levels. The remaining seven samplers were placed downwind to measure elevated aerosol levels due to operation of the spray source.

During Pre-Fair studies emphasis was placed on characterization of source strength and identification of pathogen survival characteristics upon aerosolization. The sampling configuration designed for the 20 Pre-Fair aerosol sampling runs is shown in Figure V. D-1. Following the eighth aerosol run, however, the five-meter station was eliminated and moved to 30 meters. This was due to the high frequency at which this station was hit with spray during wind gusts. Late in the Pre-Fair study period, it was determined that more duplicate samples at a given distance were required to better estimate source of variability. Thus, one of the following configurations was used during the last five aerosol runs:

Configuration A		Configuration B	
No. of Samplers	Distance	No. of Samplers	Distance
1	upwind	1	upwind
2	10 meters	2	20 meters
1	20 meters	1	30 meters
1	30 meters	1	40 meters*
1	40 meters*	2	50 meters*
2	50 meters*		

* double samplers at these distances were alternated on different runs.

Emphasis during Post-Fair studies was on modeling of downwind aerosol concentrations. Thus,



X Upwind (at a great distance)
WIND DIRECTION
SPRAYER LINE
90°
θ
Wet Line Edge
5 m
10 m
20 m
1/2 maximum distance (usually 50 m)
SAMPLER LINE
maximum distance (usually 100 m)

Figure V.D-1.
AEROSOL SAMPLING CONFIGURATION FOR PRE-FAIR

the configuration used for the 29 Post-Fair aerosol sampling runs (Figure V. D-2) required the placement of samplers at greater distances (up to 600 meters) from the spray source.

During both Pre- and Post-Fair studies, detailed protocols were prepared to provide guidance to field personnel. These included instructions by which the real-time on-site meteorological measurements should be used to determine: specific sampler locations; criteria for initiating or aborting aerosol runs, and whether collected samples should be shipped for analysis (good run) or discarded (bad run).

2. Dye Aerosol Runs

Dye aerosol runs were conducted during both Pre- and Post-Fair to determine the percent of sprayed wastewater that left the spray field as aerosol. Thus, a close-in configuration, as shown in Figure V. D-3 for the Post-Fair runs, was used for the eight AGI samplers used during Pre- and Post-Fair study periods respectively. Again detailed instructions were prepared to guide field personnel on the placement of samplers relative to wind direction and on the meteorological conditions necessary to initiate/accept as valid each run.

3. Quality Assurance Runs

Eight quality assurance runs were conducted (5 during Pre-Fair and 3 during Post-Fair studies). In each, all functioning samplers were placed side-by-side (separated by one meter in Pre-Fair and three meters in Post-Fair) at the same distance from the spray field. A randomized arrangement of samplers on both sides of the center line permitted evaluation of bacterial analyses precision (both within- and between-samplers) and a determination of systematic differences in the collection efficiency of the various high volume samplers.

4. Special Enteric Virus Aerosol Runs

During Pre-Fair studies, assays of the high-volume aerosol sampler collection fluid for enteric virus were consistently negative. This was due to their relatively low concentration in the wastewater and the inadequate sensitivity of the sampling procedure employed. Even at low concentrations, enteric virus aerosols could represent a significant hazard to human health. Therefore, a special sampling protocol was designed for Post-Fair studies to significantly improve the procedure's sensitivity and, thus, provide quantitative measurements of enteric virus aerosol concentrations. These special virus aerosol runs were designed to characterize source strength by placing all available aerosol samplers (12 or 13 samplers) side-by-side at a 50-meter distance from the spray source. The samplers were then operated for many consecutive aerosol runs (four for the first virus run and six for the second virus run). The 100 mL of collection fluid from each sampler, during each run, was placed in a common container. The total volume was then transported to the laboratory where it was concentrated and assayed to provide a single estimate of the enteric virus aerosol concentration. This represented an approximately 50-fold increase in the sampling procedure's sensitivity. Since all samples had to be pooled to obtain a single concentration estimate, the procedure could not provide an estimate of the variability associated with this measurement. Two such sampling runs were conducted during Post-Fair studies.

E. Data Flow, Processing and Analysis Methods

1. Sample Identification and Labeling

To develop valid findings from this large-scale field sampling and analysis effort, it is essential that the identity and integrity of the data be preserved. Accordingly, an integrated data system involving a unique sample code, computer-generated sample labels, field data reporting forms, and analytical data reporting forms was implemented. This system insured that each sample was uniquely identified (run number, sample location, medium, analysis, sampling period) and that this identity was transmitted with the analytical values from sample collection through processing, shipping , preparation, analysis, reporting, and statistical analysis. This uniform accounting and tracking procedure also made it impossible for laboratory personnel to iden-

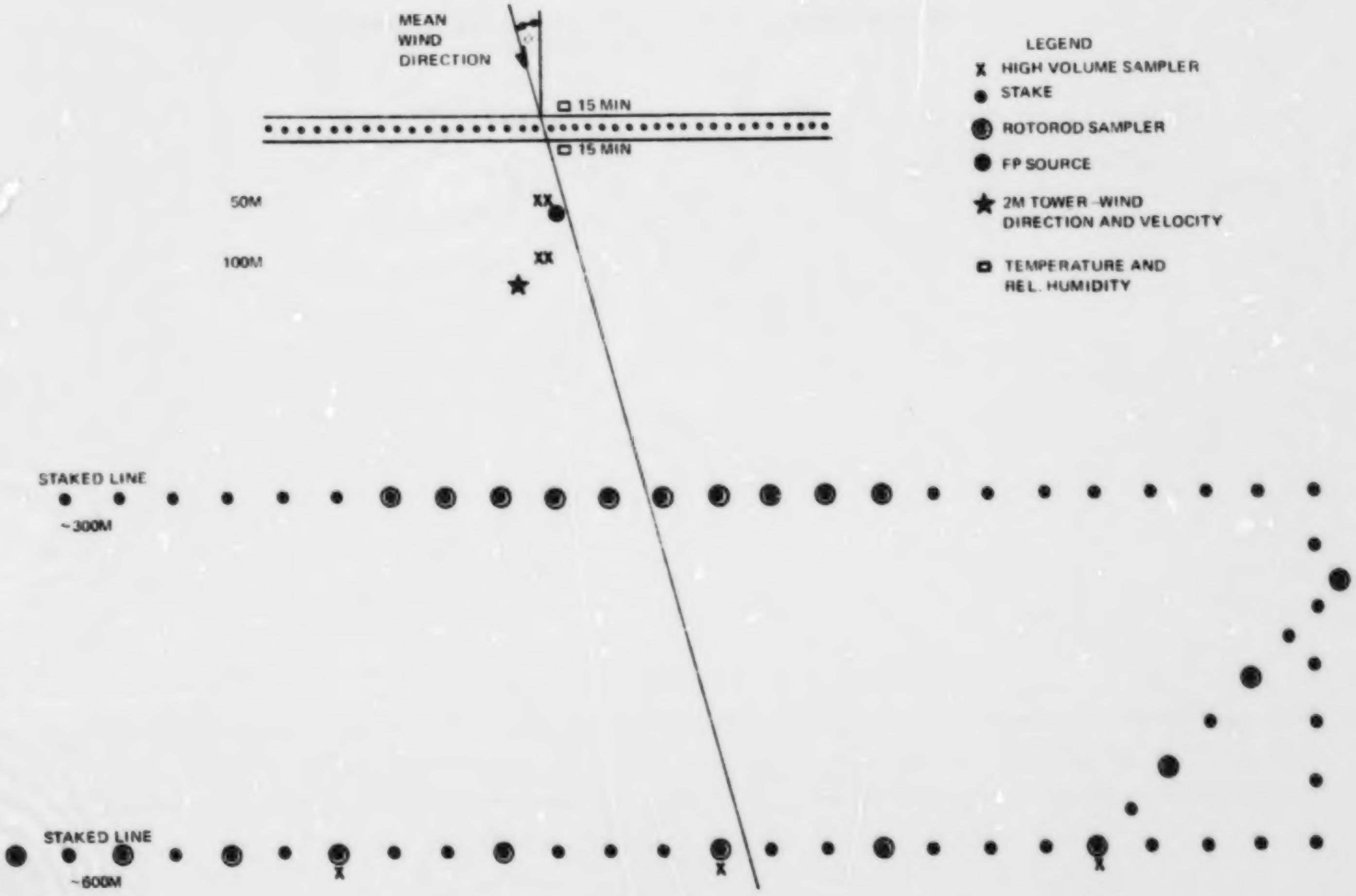

MEAN
WIND
DIRECTION
15 MIN
15 MIN
50M
100M
XX
XX
LEGEND
X HIGH VOLUME SAMPLER
● STAKE
ROTOROD SAMPLER
FP SOURCE
★ 2M TOWER - WIND DIRECTION AND VELOCITY
TEMPERATURE AND REL. HUMIDITY
STAKED LINE
~300M
STAKED LINE
~600M
X
X
X

Figure V.D-2.
PRIMARY (MICROBIOLOGICAL) AEROSOL SAMPLING CONFIGURATION FOR POST-FAIR

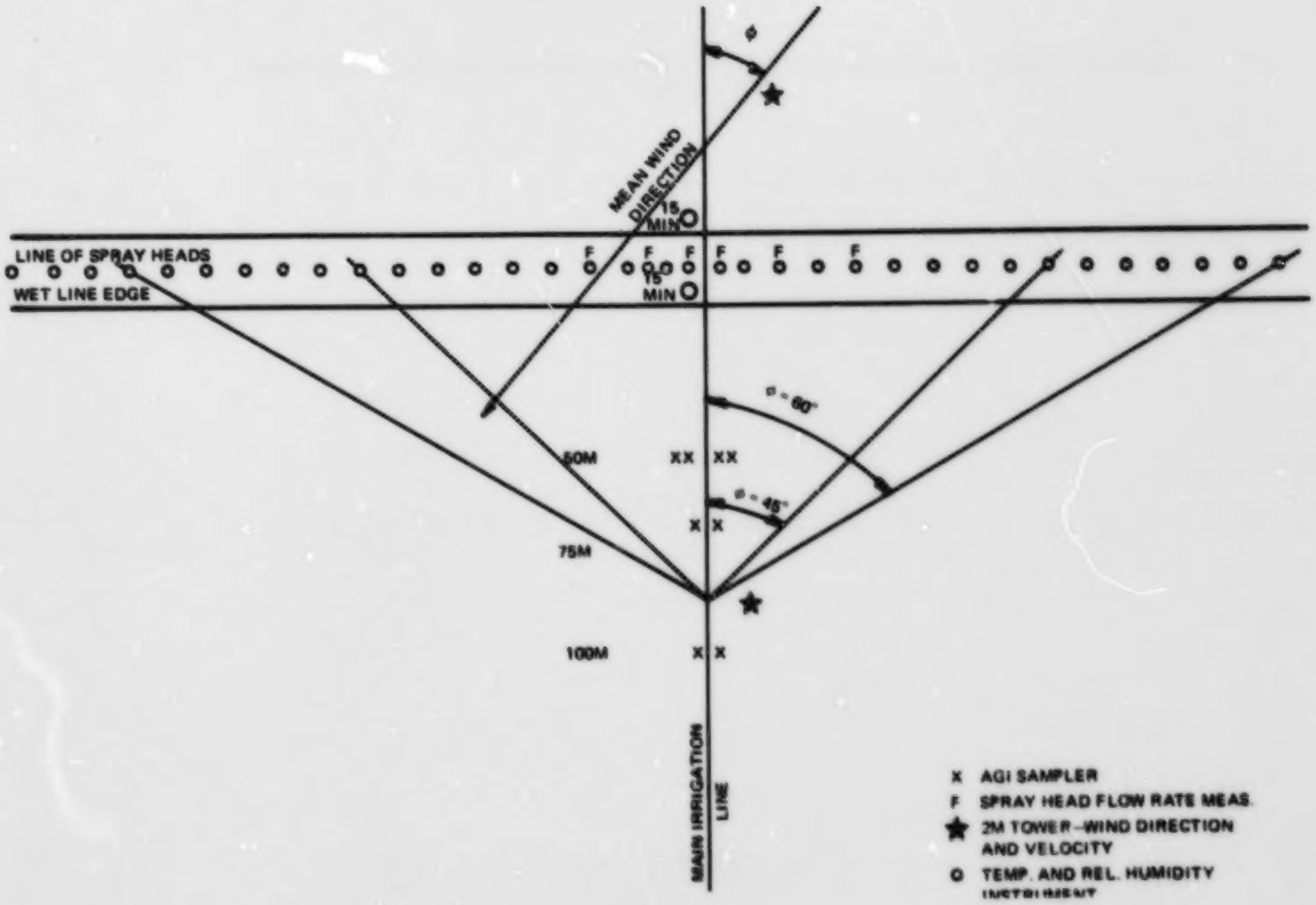

φ
MEAN WIND DIRECTION
15 MIN
LINE OF SPRAY HEADS
F
WET LINE EDGE
15 MIN
θ = 60°
θ = 45°
50M
75M
100M
MAIN IRRIGATION LINE
X AGI SAMPLER
F SPRAY HEAD FLOW RATE MEAS.
★ 2M TOWER–WIND DIRECTION AND VELOCITY
O TEMP. AND REL. HUMIDITY INSTRUMENT

Figure V.D-3.
DYE AEROSOL SAMPLING CONFIGURATION FOR POST-FAIR

tify samples and, thus, introduce bias into their analyses. This was extremely important for the quality assurance samples which were also submitted using this code system.

2. Data Forms and Reporting System

In conjunction with the sample labeling system, a series of forms was prepared and a reporting procedure established to insure close coordination and control of the field and laboratory aspects of the study. Field and laboratory personnel submitted completed forms on a routine basis to the project statistician, where they were reviewed for data reporting deficiencies and for sampling and analysis problems. This provided a timely feedback mechanism to correct errors and to identify requirements to modify the study protocol.

3. Aerosol Data Processing

Ideally, the measured microbiological aerosol concentrations are presumed to accurately describe the microorganism levels emanating from the source under study (e.g., the line of sprayers). However, in a large-scale field program such as that conducted at Pleasanton, some measurements of microbiological aerosol concentrations are likely to reflect extraneous factors such as sampler/sample contamination or nonstudy sources that dominate the study source effect. In addition, the high variability of quantum microbiological measurements at levels close to the minimum detection limits of the methods used requires careful data smoothing techniques to avoid logical inconsistencies. The extraneous factors and variability-induced logical inconsistencies can have biasing and mathematically intractable consequences in data analyses such as the microbiological dispersion model development. Procedures developed and used to alleviate these data analysis problem areas include:

(a) a procedure for standard data processing and event notation,

(b) a procedure for use/rejection of data based on evidence of sampler/sample contamination, and

(c) data smoothing procedures used for application of the microbiological dispersion model.

4. Computational Techniques

The automated computational techniques which were used to analyze the extensive data generated during this project were chosen as being the most appropriate from numerous options that were available. SwRI currently maintains a special lease arrangement with the McDonnell Douglas (McAuto) computer facility in Huntington Beach, California for use of their CDC Cyber 70/74 equipment. This system is accessed through a CDC remote batch terminal at the Institute's Computer Laboratory. In addition, a Hewlett Packard 9810A programmable calculator with a limited package of statistical routines was utilized when the desired analysis was less involved and the quantity of data was sufficiently small to permit direct keyboard entry. The major automated computational procedures used in this project are listed in Table V. E-1.

5. Statistical Approach

The specific objectives given in Section III. D. have been addressed by applying suitable statistical methods to the study data to make appropriate inferences (i.e. findings). Statistical analyses relevant to many of the objectives were performed upon obtaining the Pre-Fair data. In some cases, the Pre-Fair analysis provided adequate information and its methods and results are presented in Section VI. In other cases, a repeated analysis encompassing both the Pre-Fair and the Post-Fair data was performed and is reported in Section VI. The Pre-Fair data analyses suggested the propriety of developing the microbiological dispersion model. Development and evaluation of this model was the major emphasis of the Post-Fair data analysis.

Table V.E-1
AUTOMATED COMPUTING PROCEDURES

Program	Source	Type	Computer System	Usage
LABELS	SwRI	New	Cyber 74	Generate sample labels.
DSTAT1	SwRI	Existing	HP9810A	Mean, standard deviation, and coefficient of variation.
DSTAT2	HP	Package	HP9810A	Calculate mean, standard deviation, skewness, kurtosis; grouped and ungrouped data.
CORREL	SwRI	New	HP9810A	Correlation coefficients
TPROB	SwRI	Existing	HP9810A	Percentiles of t-distribution.
ANOVA	HP	Package	HP9810A	Analysis of variance, one-way and two-way without interaction.
PRESTO	SwRI	Existing	Cyber 74	Stepwise multiple linear regression; correlation coefficients.
CANCORR	SPSS	Package	Cyber 74	Canonical correlation; correlation coefficients,
CONDESCRIPTIVE	SPSS	Package	Cyber 74	Calculate mean, standard deviation, skewness, kurtosis.
BMD08V	BMD	Package	Cyber 74	General analysis of variance models.
BIODCAY	SwRI	New	Cyber 74	Calculate estimates of microbiological dispersion model parameters I and λ.
MODEVAL	SwRI	New	DG Eclipse 300	Evaluates the microbiological dispersion model by comparing its prediction P against the observed value C-B.

VI. RESULTS

A. Wastewater Characteristics

1. Chemical Data and Patterns

The results of water quality chemical analyses indicated that the Pleasanton wastewater was generally typical of an undisinfected, secondarily treated wastewater. Mean values for certain parameters, determined during Pre-Fair studies, were as follows: BOD - 18.7 mg/L, COD - 99.5 mg/L, TOC 33.0 mg/L, ph 8.4, hardness 235.2 mg/L, TSS - 33.0 mg/L, total phosphorus - 5.6 mg/L and nitrite, nitrate, ammonia and organic nitrogen - 0.15 mg/L, 0.06 mg/L, 23.9 mg/L and 5.6 mg/L, respectively. Limited chemical analyses continued during Post-Fair studies and revealed no major differences in wastewater quality.

A strong relationship was observed among TOC, COD, and BOD. The significance level of the correlation between TOC and BOD was 0.006, and for the other pairs it was less than 0.001.

In general, no major wastewater quality differences were observed on a weekly or daily basis or during the conduct of any individual aerosol runs. Thus, the chemical quality of the wastewater was not considered to have a significant influence over the variability of the microbiological aerosol levels measured.

These results do not imply that water quality has no effect on microorganism survival. Chemical parameters may, in fact, have adverse (toxic) or beneficial (protection from desiccation) effects on the survival of aerosolized microorganisms. Thus, water quality may have had an overall impact on the actual levels of microbiological aerosols measured that could not be evaluated during this study. Since the water quality was relatively consistent throughout the study period, it was not considered a reliable indicator/predictor of microorganism (especially pathogen) levels. Thus, the chemical quality of the wastewater was not considered a relevant factor for inclusion in the microbiological dispersion model. A complete description of the wastewater chemical data and patterns is presented in Appendix E.

2. Microbiological Data and Patterns

a. Daily Composite Microbiological Data

Samples from the daily composite effluent sampler during Pre-Fair were sent to Pacific Environmental Laboratory (PEL) for microbiological analyses of standard indicator microorganisms, including total and fecal coliform and standard bacterial plate count, or the total aerobic bacteria plate count with standard methods medium. The concentration values obtained are shown in Table VI. A-1. Since the totl coliform and fecal coliform analyses were performed using the membrane filter method, these values are reported as MFC/100ml (membrane filter count per 100 milliliter of effluent).

The total and fecal coliform values shown are the average of a minimum of three repetitions, and often five or six. Standard bacterial plate count was generally performed in either duplicate or triplicate and the average value is shown for these as well. There was only one sample which gave unusual values, sample 78 from June 12, where there was apparently some contamination of the sample. The laboratory was unable to complete the analysis for fecal coliform on sample 74 due to an equipment malfunction.

As can be seen from the table, the concentrations were fairly consistent during given intervals within the sampling period. In addition, all three measurements exhibited similar indications of changes in the effluent microbiological constituents.

Portions of the daily composite effluent samples were shipped to the UTSA-CART laboratory for analyses for coliphage, selected pathogenic bacteria, and enteric viruses. The concentration values for these daily effluent samples are presented in Table VI. A-2. Following the table is a list of footnotes. The

Table VI.A-1.

DAILY COMPOSITE EFFLUENT CONCENTRATIONS OF MICROBIOLOGICAL INDICATOR PARAMETERS

Sample No.	Date	Total Coliform (MFC/100 ml × 10^3)	Fecal Coliform (MFC/100 ml × 10^3)	Standard Plate Count (No./100 ml × 10^4)
1-2	5-2	1700	117	130
2	3	2300	275	250
3	4	2500	210	100
4	5	2200	180	110
5*	7	1350	147	76.7
32*	8	750	93.3	77
33*	9	517	102.7	107
34*	10	832	126	91.7
35*	11	1200	143	157
36	11	913	68	180
37	12	255	36.7	57
98	13	817	82.7	237
71	14	958	123	120
1-3	15	1220	90	247
61	16	477	59.5	110
70	17	410	12.5	34.3
41	18	420	33.3	75.7
76	19	617	63	133
67	20	713	177	115
38	21	830	82.8	75
75	22	1200	152	393
64	23	1060	140	218
39	24	800	123	85
62	25	992	83.3	57
99	26	533	33.7	101
74	27	763	†	13.5
63	28	1450	134	133
40	29	1430	220	90
97	30	565	53	62.7
60	31	817	76.7	96.7
73	6-1	703	57	133
42	2	293	24.3	102
69	3	267	24.3	35
66	4	833	59	107
95	5	530	35	63.5
68	6	257	13	157
77	7	417	59	11.3
72	8	160	22.3	36
65	9	760	85.7	19.3
96	10	798	80.4	15.7
43	11	290	31.3	11.7
78‡	12	2470	263	>300
50	13	490	70.3	14
51	14	743	93.2	12.7
52	15	620	79	21.3
53	16	340	82.3	14.7
56	17	530	63.3	6.13
58	22	353	64	8.05

*Composite sampler inoperative, grab sample taken morning after spraying.

†Equipment malfunction; laboratory unable to perform analysis.

‡Probable contamination.

Note: 1700 (MFC/100 ml X 10^3) = 1700 X 10^3 MFC/100 ml = 1.7 X MFC/100 ml

Table VI.A-2.
DAILY COMPOSITE EFFLUENT CONCENTRATIONS OF COLIPHAGE AND SELECTED PATHOGENIC BACTERIA AND VIRUSES

Sample Date	Coliphage Count, (PFU/l) × 10³	Bacteria				Viruses		High Sample Temperature Upon Lab Receipt
		Klebsiella, (CFU/100 ml) × 10³	Pseudomonas, (CFU/100 ml) × 10³	Streptococci, (CFU/100 ml) × 10³	Clostridium perfringens, (MPN/100 ml) × 10³	3-Day Plaques (PFU/l)	5-Day Plaques (PFU/l)	
5-2-76	68		CS	CS	>24	9.9	TNTC	
5-3-76	370		100	>24†	11	4.6	TNTC	
5-4-76	CS		25	CS	11	340*	TNTC	
5-5-76	120		15	CS	>24	29	TNTC	
5-6-76	160		90	CS	4.6	589*	TNTC	
5-7-76	180		140	9.3†	1.1	18	36	10°C
5-8-76	110		88	CS	.46	25	TNTC	
5-9-76	87		110	11†	>2.4	26	28	
5-10-76	97		50	11†	.24	<2.4	4.7	
5-11-76	100		25	CS	.24	4.7	9.8	
5-12-76	140		13	2.3†	.093	12	16	7°C
5-13-76	540	25	80	>24†	11	33	31	9°C
5-14-76	350	39	75	4.6†	9.3	7†	90	9°C
5-15-76	290	58	25	23†	9.3	<1.8	15	
5-16-76	230	41	15	10	4.6	20	43	
5-17-76	97	29	30	6.5	4.6	21	43	
5-18-76	360	36	60	5.1	4.6	19	26	
5-19-76	330	28	50	7.9	4.6	15	24	
5-20-76	340	52	25	13	7.5	39	39	
5-21-76	190	55	210	20	>24	18	18	
5-22-76	260	72	120	18	23	9.3	9.3	
5-23-76	120	CS	250	10.4	4.3	1.3	3.3	
5-24-76	78	52	35	8.0	24	CS	CS	
5-25-76	130	55	120	2.8	46	CS	CS	
5-26-76	120	28	90	3.7	9.3	5.3	7.2	

*Possible contamination.
†MPN.

Table VI.A-2 (continued)

Sample Date	Coliphage Count, (PFU/l) × 10³	Bacteria				Virus		High Sample Temperature Upon Lab Receipt
		Klebsiella, (CFU/100 ml) × 10³	Pseudomonas, (CFU/100 ml) × 10³	Streptococci, (CFU/100 ml) × 10³	Clostridium perfringens, (MPN/100 ml) × 10³	3-Day Plaques (PFU/l)	5-Day Plaques (PFU/l)	
5-27-76	180	94	30	6.8	4.3	15	15	
5-28-76	240	44	1700	9.6	4.3	4.7	CS	
5-29-76	410	39	2900	14.6	4.3	4.7	6.8	
5-30-76	290	25	450	2.5	2.3	18	18	
5-31-76	230	36	1900	10.3	7.5	<1.6	8.8	
6-1-76	160	41	100	5.7	9.3	4	66	
6-2-76	270	17	300	1.7	9.3	17	23	
6-3-76	280	30	200	2.3	4.3	45	50	
6-4-76	350	8.2	350	6.6	2.3	60	86	
6-5-76	280	17	260	4.3	2.3	56	87	
6-6-76	200	33	430	4.2	2.3	27	CS	
6-7-76	330	36	92	3.4	4.3	46	CS	
6-8-76	440	19	45	1.1	15	CS	CS	
6-9-76	570	50	130	5.7	9.3	5.9	CS	
6-10-76	490	50	120	12	9.3	<1.9	<4.0	
6-11-76	460	110	200	34	4.3	10	16	
6-12-76	360	55	150	3.0	4.3	22	22	
6-13-76	420	28	95	6.4	9.3	4.6	4.6	
6-14-76	350	58	30	17.1	9.3	7.9	7.9	
6-15-76	220	41	25	9.2	9.3	6.1	CS	
6-16-76	230	33	30	5.5	4.3	12	14	
6-17-76	220	94	20	4.0	9.3	12	14	

PFU –Plaque forming units.
CFU –Colony forming units.
MPN –Most probable number.
TNTC –Too numerous to count.
CS –Contaminated sample.
M –Missing

pathogenic bacteria selected for assay were *Klebsiella*, *Pseudomonas*, fecal streptococci, and *Clostridium perfringens*. The *Klebsiella* column of Table VI. A-2 consists of *Klebsiella pneumoniae* and *Klebsiella ozaenae*. The *Pseudomonas* reported in Table VI. A-2 are fluorescent.

The streptococci column gives the fecal streptococci assayed according to *Standard Methods for the Examination of Water and Wastewater*. The *Klebsiella*, *Pseudomonas*, and later streptococci assays are reported as CFU/100 ml (colony forming units for 100 milliliters of effluent). The early streptococci values and the *Clostridium perfringens* values were obtained through analyses requiring most probable number tables; these values are reported as MPN/100 ml (most probable number per 100 milliliters of effluent). Viruses in the effluent samples were plated on HeLa cell monolayers. Approximately 70% of each concentrated sample was observed for virus plaques after three days; the remainder of each sample was observed after five days. The 3- and 5-day virus counts in Table VI. A-2 are given in PFU/l (plaque forming units per liter of effluent). See Appendix D for a complete description of the microbiological analysis procedures performed on the effluent samples.

The first daily composite sample sent for coliphage analysis was concentrated. However, its titer was high enough (91% efficiency) to establish that concentration was unnecessary for the coliphage analyses of the remaining daily composite samples. Concentration was found to be necessary, and was conducted, on all the effluent samples assayed for viruses. The recovery efficiency of the daily poliovirus reference samples ranged from 15 to 100%. The quartiles of the recovery efficiency distribution were 39% (first quartile), 50% (median), and 65% (third quartile). The corrected virus plaque count shown in Table VI. A-2 was obtained by dividing the observed raw plaque count by the recovery efficiency for that day's reference sample. Since quantitative effluent concentrations were obtained on nearly every sample, the data are suitable for statistical analyses.

As anticipated with such a large-scale systematic sampling and analysis protocol, there were also a few problems. Some early bacteria and virus samples and several of the later virus samples were contaminated. Two or three of the early virus samples may have been contaminated with the reference poliovirus. Four of the early sample shipments were received at temperatures considerably above the desired 4°C. The elevated temperatures may have raised the bacterial pathogen levels and lowered the coliphage and virus levels of these samples in comparison with the samples shipped at about 4°C. Streptococci levels were determined by the MPN method for the first two weeks because the proper assay medium was unavailable.

Several special data symbols have been used in Table VI. A-2. When the sample assay was negative, the result has been reported as <(less than) the detection limit. The virus and coliphage plaque-forming units grow as they consume the host cells. When the individual virus plaques grew together, it was impossible to determine how many plaque-forming units there were; such results were reported as TNTC (too numerous to count).

It is important to note that a wide range of effluent concentration values was observed. The coliphage, bacteria, and virus concentrations in Table VI. A-2 and the coliform and standard bacterial plate count concentrations in Table VI. A-1 all exhibit at least a one order of magnitude range of values. Many approach a two orders of magnitude range. In fact, *Pseudomonas* and *Clostridium perfringens* vary over more than two orders of magnitude.

b. Distributional Characteristics

Summary statistics were calculated for all wastewater microorganism concentration data. The mean, standard deviation, skewness, and kurtosis statistics, given in Table VI. A-3, characterize the effluent sample distribution of each. The upper half of the table applies to the untransformed data. The arithmetic standard deviations are large relative to the arithmetic means for each parameter, which implies the orders of magnitude variation readily observed in Tables VI. A-1 and VI. A-2. The skewness and kurtosis

Table VI.A-3.
DISTRIBUTIONAL CHARACTERISTICS OF THE WEIGHTED DAILY AND LARGE—VOLUME EFFLUENT SAMPLE CONCENTRATIONS OF THE INDICATOR AND PATHOGENIC MICROBIOLOGICAL PARAMETERS

	No. of Samples with Numeric Analysis Results	Effluent Sample Statistics				P, Significance Levels of One-Sided Tests of Suitability of Normal Distribution Model	
		Mean	Standard Deviation	Skewness	Kurtosis	Skewness (H_0: $\sqrt{\beta_1} = 0$)	Kurtosis (H_0: $\beta_2 = 3$)
Untransformed Concentration		(Arithmetic)					
Total Coliform, (MFC/100 ml) × 10^3	54	927.9	650.9	1.5	5.0	<.01	<.01
Fecal Coliform, (MFC/100 ml) × 10^3	53	102.2	71.8	1.3	4.7	<.01	.01
Std Plate Count, (No./100 ml) × 10^5	53	106.3	95.9	2.1	9.6	<<.01	<<.01
Coliphage (PFU/l) × 10^3	53	258.1	130.8	0.5	2.4	.05	OK
Klebsiella, (CFU/100 ml) × 10^3	42	44.9	23.0	0.8	3.5	.01	OK
Pseudomonas, (CFU/100 ml) × 10^3	52	264.1	525.9	3.6	16.0	<<.01	<<.01
Streptococci, (CFU/100 ml) × 10^3	46	8.84	7.55	2.2	10.3	<<.01	<<.01
Clostridium perf, (MPN/100 ml) × 10^3	53	9.06	10.14	2.8	10.7	<<.01	<<.01
3–Day Virus Count (PFU/l)	48	20.6	28.9	5.5	42.1	<<.01	<<.01
5-Day Virus Count, (PFU/l)	39	27.9	35.4	4.3	27.3	<<.01	<<.01
Natural Log Transformed Concentrations		(Geometric)					
ln (Total Coliform)	54	748.5	1.24	0.02	2.68	OK	OK
ln (Fecal Coliform)	53	79.5	1.33	-0.41	2.84	OK	OK
ln(Std. Plate Count)	53	69.9	1.68	-0.57	2.63	.04	OK
ln (Coliphage)	53	223.9	1.17	-0.37	2.18	OK	.05
ln (*Klebsiella*)	42	38.8	1.19	-0.88	4.23	.01	.04
ln (*Pseudomonas*)	52	104.8	2.18	0.61	3.16	.03	OK
ln (Streptococci)	46	6.73	1.39	-0.40	3.49	OK	OK
ln (*Clostridium perf*)	53	5.39	2.02	-1.15	4.98	<<.01	<.01
ln(3-Day Virus Count)	48	12.11	1.81	-0.41	3.41	OK	OK
ln(5-Day Virus Count)	39	17.29	1.61	0.06	2.89	OK	OK

statistics test whether the distribution is normal. A skewed distribution has one tail that extends out farther than the other tail. Kurtosis measures whether the distribution has a very sharp peak or a very broad, flat top. The true normal distribution has a skewness parameter of 0 and a kurtosis statistic of 3. For each set of microbiological concentration data, tests of the null hypotheses that the data were normally distributed were conducted. The significance levels of the results are presented in the two right-hand columns of Table VI. A-3. All of the untransformed data exhibited positive skewness. Only the untransformed data for coliphage and possibly for *Klebsiella* had acceptable normal distribution kurtosis. This confirmed the requirement to transform the effluent microbiological data to permit valid correlation analysis.

The summary statistics under the natural log transformation are shown in the lower half of Table VI. A-3. To permit comparison with the untransformed data statistics, the geometric mean and the geometric standard deviation are given in Table VI. A-3, rather than the ln x mean and standard deviation. The geometric mean has the same units as the arithmetic mean. The geometric mean values are lower than the arithmetic mean because of the scale adjustment introduced by the logarithmic transformation.

The results of the skewness and kurtosis tests of the normal distribution null hypotheses are also given in Table VI. A-3 for the natural log transformed data. For most microorganism groups, both the skewness test and the kurtosis test indicate that the logarithmic transformed data have an acceptabel normal distribution (i.e., the untrasnformed data have a lognormal distribution). For each of the others the natural log data are more nearly normally distributed than are the untransformed data. Neither the natural log transformation, the square root transformation, nor the untransformed data for *Clostridium perfringens* followed a normal distribtuion. This may be due to the limited number of *Clostridium perfringens* values permitted in the MPN index probability tables rather than an actual characteristic of the concentration levels. Except for the effluent *Clostridium perfringens* data, each of the effluent microorganisms were generally considered to follow a lognormal distribution.

c. *Wastewater Analysis Variability*

A precision study for the three indicator microorganism group analyses was conducted during Pre-Fair in the same manner as for the chemical constituents. The replicate determinations from the daily effluent runs were used to obtain estimates of the standard deviations associated with analytical repeatability. The data used were transformed by the natural logarithms of the observed counts to achieve normality and homogeneity of variance. The standard deviations were then pooled and the results exponentiated to obtain the estimates of variance due to repeat analysis.

Ten samples were sent for analysis, five from each of two 500-ml grab samples (which were split from a single 1 liter grab) to determine the shipping and analysis variance component. The results for these samples and the standard deviations of the transformed data obtained are shown in Table VI. A-4. The standard deviations for the 2 pond grab samples are pooled into a single estimate as above and exponentiated to give an estimate of the percentage variation among the samples. The day-to-day variance estimate is taken from the summary statistics portion of Table VI. A-3. The three variance components estimated for each microorganism group are presented in Table VI. A-5.

The total coliform data show no tendency to be affected by the shipping process, giving approximately equal values for both the repeatability and between-sample components. The fecal coliform analysis has a higher standard deviation for shipping and analysis than repeatability, but an F-test performed in

Table VI.A-4.
MICROBIOLOGICAL INDICATOR QUALITY ASSURANCE PRECISION STUDY—ANALYTICAL RESULTS

		Parameter		
Grab	Sample	Total Coliform (MFC/100ml x 10^3)	Fecal Coliform (MFC/100ml x 10^3)	Standard Plate Count (no/100 ml x 10^6)
1	1	570	64.3	108
	2	543	77.8	57
	3	483	44.3	23.8
	4	577	55.0	230
	5	477	63.3	150
2	1	575	72.5	195
	2	650	46.7	160
	3	543	42.0	49.7
	4	603	56.7	108
	5	633	47.5	137
Coefficients of variation		8%	24%	109%

Table VI.A-5.
MICROBIOLOGICAL QUALITY ASSURANCE PRECISION STUDY—PRECISION ESTIMATES
(Percent Coefficient of Variation)

	Parameter		
Variance Component	**Total Coliform**	**Fecal Coliform**	**Standard Bacterial Plate Count**
Repeatability	11	11	12
Shipping and Analysis	08	24	107
Day to Day	24	33	118

the transformed scale does not indicate a significant difference between the two components. The standard bacterial plate counts are more variable. A variance component estimated from these data is 1.09, or 9-percent variation from sample to sample induced by the shipping and handling, plus between-sample variability.

The precision portion of the quality assurance study on the analysis for coliphage and pathogens was conducted using replicate portions from two effluent grab samples. The coliphage was analyzed in five replicates from each of the two samples and the pathogenic bacteria and viruses were analyzed in three replicates from each sample. The data are used to estimate analytical variability, within replicates, and to determine if there is a significant between-sample variance associated with these data. All analyses were performed in the logarithmic scale on the basis of the distributional nature of the data.

The coliphage data are presented in Table VI. A-6, along with the variance components calculated for the two components. The pooled within replicate standard deviation is 0.13 in the transformed data. Exponentiating gives 1.14, or 14% variability from sample to sample. The standard deviation between samples is 0.061, which is smaller than the replication error estimate and hence insignificant. The implication is that the observed variability is, in fact, replication error.

The data from the selected pathogenic bacteria analyses are presented in Table VI. A-7. As in the coliphage data above, standard deviations are calculated for the results from each sample, then pooled to obtain an overall estimate.

For *Klebsiella*, the pooled replication standard deviation is 0.26 in the transformed data, which when exponentiated gives 1.30 in the original scale. This implies that there is 30-percent variability from one analytical result to another from replicates of the same effluent sample. The difference between the means of the two groups gives an estimated standard deviation of 0.36, and again the between-sample term is insignificant.

The *Pseudomonas* data give a pooled standard deviation of 0.27 under the transformed scale, which gives 1.31 or 31-percent variability in the original scale. This is to be compared with the variability between the means of the two groups. This is estimated as 0.54, which is not significantly different. As a result, the six values may be considered replicates in the usual sense.

The streptococci results from within each 500-mL grab sample yield a pooled replication standard deviation of 0.13, and when exponentiated gives 1.14, or an estimated 14-percent variability between the samples within a given pond grab sample. The mean values give a standard deviation under the transformation of 0.06, and once again is less than the replication error and insignificant.

Table VI.A-6.
PRECISION QUALITY ASSURANCE STUDY FOR COLIPHAGE

Grab	Sample	Corrected Count (pfu/l × 10^5)	Standard Deviation (ln X)
1	6	4.5	0.06
	7	4.6	
	8	5.3	
	9	4.8	
	10	4.7	
2	11	4.3	0.17
	12	3.6	
	13	4.4	
	14	5.7	
	15	4.9	

The *Clostridium perfringens* results have a standard deviation of 0.21 in the transformed scale for replication error in analyzing the same effluent sample. This corresponds in the original scale to a value of 1.23, or 23-percent variability. The difference in the mean values is represented by a standard deviation of 0.39, which again represents an insignificant difference.

In summary, for all the bacterial analyses, no variation between samples was detectable, and the only discernable variability was due to analytical repeatability.

Table VI.A-7.
PRECISION QUALITY ASSURANCE STUDY FOR BACTERIA

		Parameter			
Grab	Sample	Klebsiella (cfu/100ml × 10^4)	Pseudomonas (cfu/100ml × 10^2)	Fecal Streptococci (cfu/100ml × 10^3)	C. Perfringens (MPN × 10^3)
1	6	5.2	1100	9.2	4.3
	7	3.8	1600	8.3	3.9
	8	4.4	800	11	3.9
Std. Dev. (ln x)		0.16	0.35	0.14	0.05
2	9	3.6	850	11	4.3
	10	3.3	850	9.0	2.3
	11	3.0	1100	9.7	2.3
Std. Dev. (ln x)		0.09	0.15	0.10	0.36

The results from the two virus analyses, 3-day count and 5-day count, are summarized in Table VI. A-8. Sample 11 was contaminated and not used in the analyses. Sample 10, though high, was not suggested to be contaminated and retained. The repeatability standard deviation for the natural logarithm of the data is 0.60, which calculates to a value of 1.82 in the original scale. This suggests that over 80-percent variability can be expected in replicate samples. The means represent a variability of only 0.16, and are much closer than the sample values. Again the between-sample term is insignificant and all error can be assumed to be replication error. This high between-sample variability is emphasized because it significantly impacts the statistical reliability of mathematical modeling efforts for virus aerosol concentrations presented later in this report.

For the 5-day count, the repeatability of the method is determined to be 0.55 in the transformed scale and 1.73 in the original scale. The between-sample component is estimated as 0.14, and no significant difference exists between these two values. Thus, for all the analyses, no differences could be found between the two samples. A summary of the estimated replication error for coliphage and all the pathogenic analyses is presented in Table VI. A-9.

Table VI.A-8.
PRECISION QUALITY ASSURANCE STUDY FOR VIRUS
(Corrected Count, pfu/l)

		Parameter	
Grab	Sample	3-Day Count	5-Day Count
1	6	24	35
	7	11	15
	8	18	25
Std.Dev. (ln x)		0.39	0.43
2	9	9.0	16
	10	31	45
	11*	852	926
Std.Dev. (ln x)		0.87	0.73

*contaminated sample

Table VI.A-9.
ESTIMATED REPLICATION ERROR FOR PATHOGENIC ANALYSES

Parameter	Coefficient of Variation, %
Coliphage	14
Klebsiella	30
Pseudomonas	31
Streptococci	14
Clostridium perfringens	23
3-Day Virus Count	82
5-Day Virus Count	73

d. *Equivalence of Composite and Pond Grab Samples*

The daily composite effluent samples, taken during Pre-Fair, represented an average of the effluent conditions in the pond near the pump over the time of spraying. At the time an aerosol run was made, however, an additional composite effluent sample was taken from a spray head on the sprinkler line. These represent the effluent quality, with respect to the microbiological indicators, over the 30-minute period of aerosol sampling. These two determinations of the microbiological constituents of the effluent were compared to indicate whether there was significant variability in these levels during a given day. This analysis was also conducted to determine the requirement for continued effluent sampling during aerosol runs or whether further studies could rely on microorganism concentration data from daily effluent composite samples.

The analysis was conducted in two parts. First, a correlation coefficient was calculated between the daily composite sample and the aerosol run composite sample and the significance of the correlation determined. Second, a comparative t-test was conducted to determine if the two types of samples could be estimating the same true mean. For these analyses, the results were transformed to normality using the natural logarithm in order to satisfy the assumptions of the statistical tests.

The comparative total coliform data are shown in Table VI. A-10 for the 25 aerosol runs conducted. The summary statistics from the two analyses are presented at the bottom of the table. The correlation coefficient for these data is estimated to be $r = 0.73$, and the t-test for significance gives a value of 5.13 with 23 degrees of freedom. These are significant at a level of less than 0.001, so that the daily and run samples can be said to be correlated. The t-test for equality of means is conducted by taking the difference between the two values for a given run and testing for a mean difference of zero. The t-statistic calculated for this test is 0.54 with 24 degrees of freedom and is clearly not significant. This implies that both samples are estimating the same mean level. Thus, the total coliform did not show a pattern of daily variability in these data.

The paired values and results of these statistical analyses for the fecal coliform are shown in Table VI. A-11. There are three missing values among these results when the laboratory was unable to perform the analyses due to equipment malfunction. The correlation coefficient for the remaining 22 pairs is estimated as $r = 0.40$, with a t-statistic of 1.97 with 20 degrees of freedom. This has a significance level of approximately 0.07, and, thus, is not significant at the 5-percent level. The t-test for equality gives a value of 0.50 with 21 degrees of freedom, which indicates that the two analyses are equivalent. The correlation analysis indicates that an increase in one is not necessarily accompanied by an increase in the other, but overall they can be said to be estimating the same level of fecal coliform in the effluent.

The standard bacterial plate count data are presented in Table VI. A-12. One value is missing since the laboratory did not perform the analysis. The estimated correlation coefficient is $r = 0.66$, and the t-statistic has a value of 4.17 with 22 degrees of freedom. This has a significance level of less than 0.001, and they may thus be considered to be correlated.

The t-test for difference of means for the standard bacterial plate count gives a test statistic of 2.96 with 23 degrees of freedom. This value is significant at the 0.01-percent level. By inspection, the aerosol effluent run samples can be seen to be estimating a higher mean level than the daily composite samples. It was noted that the pipes carrying the water to the spray fields were not free of material, and as a result, the water may be increasing in microbiological constituents, other than coliform, after it leaves the ponds.

The final indicator is the coliphage count data, presented in Table VI. A-13, for the twenty ordinary aerosol runs and the two quality assurance runs. On the first run, neither the daily nor the run sample produced a valid result, and on run 34, no analytical results were obtained for the run sample. The estimated correlation coefficient for the remaining 20 pairs of counts is 0.50, and the corresponding t-statistic is calculated as 2.42 with 18 degrees of freedom. This is a significant value at the 0.05 level, and the values may be said to be correlated. The test for difference between means gives a test statistic of 0.68 with 19 degrees of freedom, and is clearly non-significant. The conclusion, therefore, is that the two samples are providing estimates of the same true mean levels.

In general, then, the results of the aerosol run effluent samples in the spray field were

Table VI.A-10.
COMPARATIVE TOTAL COLIFORM DATA—DAILY vs. RUN SAMPLE

		Daily Sample	Spray Sample
Run Number	Date	(MFC/100 ml x 10^3)	
1	5-4	2500	1480
2	4-5	2200	2070
3	5-5	2200	2140
4	5-13	817	690
5	5-13	817	720
6	5-17	410	930
7	5-17	410	700
8	5-21	830	950
9	5-24	800	1040
10	5-24	800	1280
11	5-25	992	1100
12	5-27	763	470
13	5-27	763	690
14	5-27	763	750
15	6-3	267	588
16-19	6-7	417	343
20-23	6-8	160	127
24-25	6-9	760	1100
26	6-10	798	758
27-30	6-13	490	267
31	6-14	743	970
32	6-15	620	265
33	6-15	620	170
34	6-16	340	550
35	6-17	530	350

Test	Correlation (r = 0.73)	Equality
t-statistic	5.13	0.54
degrees of freedom	23	24
significance level	<0.001	not significant

strongly related to those of daily composite samples from the effluent pond. The estimated correlation coefficients do not indicate a high degree of associativity, even though they are significant for the most part. The amount of the explained variation, estimated by r^2, has a maximum value of 54 percent for the parameters studied, which is not particularly high. The more important result is that for all the parameters except standard bacterial plate count, the two results are estimating the same mean value. From these data it was concluded that daily composite samples were not necessary during Post-Fair studies.

Table VI.A-11.
COMPARATIVE FECAL COLIFORM DATA—DAILY vs. RUN SAMPLE

		(MFC/100 ml x 10^3)	
Run No.	**Date**	**Daily Sample**	**Run Sample**
1	5-4	210	150
2	5	180	186
3	5	180	174
4	13	82.7	97
5	13	82.7	180
6	17	12.5	75
7	17	12.5	110
8	21	82.8	80
9	24	123	81
10	24	123	125
11	25	83.3	124
12	27	-- *	-- *
13	27	-- *	-- *
14	27	-- *	-- *
15	6-3	24.3	57
16-19	7	59	59.5
20-23	8	22.3	14
24-25	9	85.7	177
26	10	80.4	75.3
27-30	13	70.3	27.7
31	14	93.2	137
32	15	79	24
33	15	79	34
34	16	82.3	81
35	17	63.3	45

Test	Correlation (r=0.40)	Equality
t-statistic	1.97	0.50
degrees of freedom	20	21
significance level	0.07	not significant

* missing data

e. Relationship of Pathogen Levels to Indicator Organism Levels

An important Pre-Fair objective regarding the effluent sample analyses was to investigate the relationships of the pathogenic organism (*Pseudomonas*, streptococci, *Clostridium perfringens*, 3-day viruses, and 5-day viruses) effluent concentrations, to the indicator organism (total coliform, fecal coliform, standard bacterial plate count, and coliphage) effluent concentrations. A common microbiological data analysis technique is to assume the existence of proportional relationships. If a pathogenic level was found to be directly related to an indicator level in the Pleasanton effluent, then the indicator measurement and the identified relationship could substitute for assay of the pathogen in later phases of this study.

An effluent sample data base was constructed to investigate the potential pathogen-indicator

Table VI.A-12.
COMPARATIVE STANDARD BACTERIAL PLATE COUNT DATA
DAILY vs. RUN SAMPLE

Run Number	Date	Daily Sample (No./100 ml x 10^{5})	Run Sample (No./100 ml x 10^{5})
1	5-4	100	110
2	5	116	120
3	5	110	--*
4	13	237	101
5	13	237	167
6	17	34.3	76
7	17	34.3	46
8	21	75	70
9	24	85	104
10	24	85	145
11	25	97	35
12	27	13.5	34
13	27	13.5	26
14	27	13.5	73
15	6- 3	35	45
16-19	7	11.3	14
20-23	8	36	36.7
24-25	9	19.3	44
26	10	15.7	34.7
27-30	13	14	12
31	14	12.7	16
32	15	21.3	20
33	15	21.3	95
34	16	14.7	54
35	17	6.13	76

Test	Correlation (r = 0.66)	Equality
t-statistic	4.17	2.96
degrees of freedom	22	23
significance level	<0.01	<0.01

*missing data

relationships. This data base consisted of the 47 daily effluent samples (the composites and the grab sample substitutes when the composite sampler was inoperative) presented in Tables VI. A-1 and VI. A-2 and the seven large-volume effluent grab samples taken for microbial characterization during Pre-Fair.

Because the data for the parameters given in Table VI. A-2 differ in validity and informational content, a procedure for adjusting certain analysis results and weighting each result was developed and applied to obtain the effluent data base. The analysis values that were missing or could not be quantified (the

Table VI.A-13.
COMPARATIVE COLIPHAGE DATA—DAILY vs. RUN SAMPLE

		(pfu/l x 10^3)	
Run No.	Date	Daily Sample	Run Sample
1	5-4	- - *	-- *
2	5	120	110
3	5	120	95
4	13	540	110
5	13	540	170
6	17	97	220
7	17	97	230
8	21	190	61
9	24	78	95
10	24	78	130
11	25	130	140
12	27	180	110
13	27	180	170
14	27	180	210
15	6-3	280	310
24	9	570	580
26	10	490	480
31	14	350	380
32	15	220	320
33	15	220	240
34	16	230	-- *
35	17	220	170

Test	Correlation (r = 0.50)	Equality
t-statistic	2.42	0.68
degrees of freedom	18	19
significance level	<0.05	not significant

* missing data

CS and TNTC designations in Tables VI. A-1 and VI. A-2) were assigned zero weight, i.e., excluded from the analysis. The extremely high 3-day virus values on the May 4 and May 6 daily samples were at first considered to be possible contamination with the concentration efficiency reference poliovirus. With the perspective of all the Pre-Fair effluent virus results, poliovirus contamination of these samples appears very likely. Since these extremely high values would have a major effect on any virus relationship present in the effluent data, these two virus values were also excluded from the analysis.

In the weighting procedure, the standard quantitative analysis values were given full weight. The inferior quantitative analysis values were assigned half the full weight. These inferior values consisted of results outside stated detection limits, results obtained by an analysis method inferior to the standard method (MPN for streptococci), results probably affected by an elevated temperature during shipment, and results reported as possible sample contamination. To quantify results outside the stated detection limits, analysis results below the lower detection limit were reset at half the lower detection limit, and analysis results above the upper detection limit were adjusted to be twice the upper detection limit. Unusually high 3- and 5-day virus values were reported for the first large-volume pond grab sample. Because these virus values were not so large as to be definite outliers, the likelihood of poliovirus contamination was less and these values were each given half weight.

A correlation analysis of the natural log transformed microbiological effluent concentration data was performed to seek relationships between pathogen-indicator parameter pairs. Of the 54 effluent samples, there were no missing values for total coliform and only one missing value each for fecal coliform, standard bacterial plate count, and coliphage. To facilitate the correlation, regression, and canonical correlation calculations, the geometric means of the data on the other 53 samples were substituted for the missing indicator value, and the substitute value was assigned half weight. A correlation coefficient was calculated for each pathogen-indicator pair over all those effluent samples for which there was a pathogen concentration value. The correlation coefficients obtained are presented in Table VI. A-14. The upper set of correlation coefficients in Table VI. A-14 are for the unweighted logarithmically transformed effluent data base. The lower set of correlation coefficients is calculated from the weighted logarithmically transformed effluent data base. The observation weight assigned each pathogen-indicator sample pair was the product of the pathogen sample weight and the indicator sample weight, standardized so that 1.00 was the average observation weight. The weighted correlation coefficients are considered more valid than the unweighted correlation coefficients, and have been used to make the relationship inferences.

Inspection of the correlation coefficients in Table VI. A-14 shows very little correlation between the pathogen and indicator effluent concentrations. There are negative correlations (between virus and coliform) as well as positive correlations (between some pathogenic bacteria and coliform). In contrast to the low correlations shown in Table VI. A-14, the correlations among some of weighted log transformed effluent indicator organisms were much higher: 0.879 for total coliform and fecal coliform, and 0.451 for total coliform and standard bacterial plate count.

The significance of the correlation coefficient between n pairs can be determined by testing the null hypothesis of no correlation between the parameters against the two-sided alternative using a t-distributed statistic with n-2 degrees of freedom. This test is only valid when at least one of the pair of variates is normally distributed. In Table VI. A-14, the significance levels of the correlation coefficients are presented for those pairs of weighted natural log transformed parameters for which the correlation coefficient was significant at the 0.05-percent level. Over the concentration ranges observed at Pleasanton, the only significant effluent pathogen-indicator correlations were: 0.362 between streptococci and total coliform (P = .01); 0.354 between streptococci and fecal coliform (P = .05); and -0.355 between the 5-day virus plaques and fecal coliform. Because the distributional analysis showed at least one parameter in every correlated pair to be lognormally distributed, the preceding correlation significance test is considered valid.

Although there were some significant effluent pathogen-indicator correlations, the indicated pairwise relationships were considered too weak to justify substitution of these relationships for future pathogen assays. However, for each of the pathogenic organisms that did have at least one significantly correlated indicator organism, a stepwise multiple linear regression was conducted on all the natural log transformed indicator organism data. The purpose was to see how well the best linear combination of the indicator organism concentration data might predict pathogenic concentrations. Weighted stepwise regression analyses were performed using as dependent variables the natural log transformations of the streptococci, *Clostridium perfringens*, and 5-day viruses effluent concentrations. In each regression, the potential regressor variables were the natural log transformations of the total coliform, fecal coliform, standard bacterial plate count, and coliphage effluent concentrations. In the weighted regression analysis, a weight must be assigned to each observation (i.e., the set of indicator and pathogen results for a sample). The observation weighting procedure used was to multiply the dependent parameter sample weight by a linear combination of the indicator parameter sample weights and divide by the standardizing average observation weight. It is desirable to give more weight to those samples for which the indicator organisms, more likely to be included in the regression equation, had quantitative values. Accordingly, the significantly correlated indicator organism weights were doubled in computing the indicator organism weight linear combination.

Table VI.A-14.

UNWEIGHTED AND WEIGHTED SAMPLE CORRELATIONS OF THE NATURAL LOG TRANSFORMED EFFLUENT CONCENTRATIONS OF THE INDICATOR AND PATHOGENIC MICROBIOLOGICAL PARAMETERS

	Pathogenic Bacteria			Pathogenic Viruses	
	Pseudomonas	Streptococci	Clostridium perfringens	3-Day Count	5-Day Count
No. of Daily and Large Volume Effluent Samples with Numeric Analysis Results	52	46	53	48	39
Correlation Coefficients of Unweighted Analyses:					
Indicator Parameters					
Total Coliform	.169	.276	.332	−.240	−.228
Fecal Coliform	.091	.264	.256	−.218	−.313
Std Plate Count	.161	.081	−.028	−.054	.166
Coliphage	.192	−.009	.121	.146	.147
Correlation Coefficients of Weighted Analyses:					
Indicator Parameters					
Total Coliform	.148	.362	.269	−.238	−.266
Fecal Coliform	.077	.354	.225	−.219	−.355
Std Plate Count	.163	.109	−.063	−.053	.126
Coliphage	.189	−.044	.143	.124	.188
Two Sided Significance Level of the Significant Weighted Analyses Correlation Coefficients:					
Indicator Parameters					
Total Coliform	–	P=.01	P=.05	–	–
Fecal Coliform	–	P=.02	–	–	P=.03
Std Plate Count	–	–	–	–	–
Coliphage	–	–	–	–	–

To simplify presentation of the statistical analyses of the microbiological effluent and aerosol sample analyses, a consistent notation has been used. This notation is shown in Table VI. A-15.

The best equations generated through the weighted stepwise regression analysis are presented in Table VI. A-16. The best streptococci regression equation involves only total coliforms. It is:

$$\ln x_{ST_e} = 0.498 \ln X_{TC_e} + 2.136$$

This equation explains only 0.136 = 13.6% of the observed variation in the streptococci effluent concentration. Thus, while it is significantly better (P = .012) than no relationship, this streptococci-total coliform relationship is not very strong. The best *Clostridium perfringens* regression equation contains the total coliform and standard bacterial plate count indicators:

$$\ln X_{CL_e} = 0.658 \ln X_{TC_e} - 0.263 \ln X_{PC_e} + 4.457$$

This regression equation has less predictive ability than the streptococci regression. It only accounts for 11.5% of the variation in the effluent sample concentrations of *Clostridium perfringens*. The negative coefficient of the standard bacterial plate count variable could suggest a negative correlation between *Clostridium perfringens* and the non-coliform bacteria. However, with a t-statistic of -1.58, this coefficient is not significant at the 0.1 level, and such an interpretation is unwarranted. The best regression equation for the 5-day virus plaque effluent concentration is:

$$\ln X_{V5_e} = -0.622 \ln X_{FC_e} + 0.611 \ln X_{CP_e} + 0.302 \ln X_{PC_e} - 3.222$$

Table VI.A-15.
MICROBIOLOGICAL CONSTITUENT NOTATION

Microbiological Constituent	Mnemonic Notation
Indicators:	
Total Coliform	TC
Fecal Coliform	FC
Standard Plate Count	PC
Coliphage	CP
Pathogens:	
Pseudomonas	PS
Streptococci	ST
Clostridium perfringens	CL
Three-day virus plaques	V3
Five-day Virus plaques	V5
Aerosol Sample	a
Effluent Sample	e
Concentration	X

Table VI.A-16.
SUMMARY OF BEST MULTIPLE REGRESSION EQUATIONS FOR PREDICTING PATHOGEN EFFLUENT CONCENTRATION FROM THE INDICATOR EFFLUENT CONCENTRATIONS

Regressed Effluent Pathogen Concentration Variable	Best Predictive Regression Equation				
	Coefficient of Multiple Determination (R^2)	Significance of Regression F-Ratio	Term in Regression Equation		
			Indicator Regression Variable	Regression Coefficient b_i	Regression Coefficient t Statistic
Ln X_{ST_e}	.136	P=.012	Ln X_{TC_e}	0.498	2.63
			1*	2.136	
Ln X_{CL_e}	.115	P=.047	Ln X_{TC_e}	.0658	2.50
			Ln X_{FC_e}	-0.263	-1.58
			1*	4.457	
Ln X_{VS_e}	.275	P=.010	Ln X_{FC_e}	-0.622	-3.12
			Ln X_{CP_e}	0.611	2.17
			Ln X_{FC_e}	0.302	2.12
			1*	-3.222	

---

*1 represents the constant term in the regression equation

The equation explains 27.5% of the observed 5-day virus variation. It is significantly better (P= .01) than no regression relationship. The 5-day virus level seems to depend somewhat on the non-fecal coliform bacteria level and the coliphage level. However, the regression coefficient t-statistics are still too small to lend much credence to such an interpretation.

The stepwise multiple linear regression equations given above are an inadequate basis for relating the pathogen and indicator effluent concentrations over the microorganism concentration ranges observed in the Pleasanton effluent. Considerably more than half of the log transformed pathogen concentration variability (i.e., pathogen percentage variation) cannot be accounted for by the variability of the indicator organism concentrations.

A third method, canonical correlation, was also employed to seek those factors that the set of pathogen measurements and the set of indicator measurements have in common over all the effluent samples. Canonical correlation might identify indicator relationships for some combination of pathogens that could not be detected by the correlation and regression analyses, which only relate one pathogen at a time. As in the correlation and regression analyses, natural log transformations of each microorganism's effluent concentration were employed to construct the analysis variables. Observation weighting was accomplished by multiplying the indicator organism weight sum by the pathogenic organism weight sum and dividing by the average observation weight. Only the 36 effluent samples, for which all nine pathogen and indicator organisms had values, were included in the initial canonical correlation analysis. The results of this analysis are summarized in Table VI. A-17. One significant pair of canonical variables was identified. The canonical correlation is 0.638. This pair of canonical variables share 0.407 = 40.7% of their variation. Wilk's lambda statistic is transformed into a chi-square statistic to determine that P = 0.041 is the statistical significance of this canonical correlation. The coefficients of the canonical variables are shown in the lower part of Table VI. A-17. The important components of the pathogen canonical variate are 5-day virus (positive coefficient) and streptococci (negative coefficient). The important indicator canonical variate components are standard bacterial plate count (positive coefficient) and total and fecal coliform (negative coefficients).

Variants of the preceding case were also analyzed by canonical correlation. The pathogenic bacteria set was related to the indicator set, but there were no significant canonical correlations. The viruses set was related to the indicator set. The one significant canonical variable pair is very similar to the significant canonical variable pair displayed in Table VI. A-17. The variable coefficients have the same signs and nearly the same magnitudes. Pairwise deletion of missing data was used to construct the basic correlation coefficient matrix from all the observations for which both parameters in each pair had numerical values. The only nearly significant (P = 0.07) canonical variable pair emerging from this analysis which used all the available data was nearly identical to the significant canonical variable pair given in Table VI. A-17.

By comparing Table VI. A-17 with Table VI. A-16, it can be seen that the one significant canonical variate pair is basically a linear combination of the regression equations for 5-day viruses and streptococci. Substituting the regression equations into the expression $0.968\ \text{LnX}_{V5_e} - 0.422\ \text{LnX}_{ST_e}$ yields a linear combination of the natural log indicator parameter that agree in sign and compare well in magnitude with the indicator set coefficients given in Table VI. A-17. Thus, canonical correlation analysis has not identified any new pathogen-indicator relationships. In fact, it strongly suggests that, beyond the meager regression relationships given in Table VI. A-16, there are no more substantive relationships among the pathogen and indicator microorganism groups in the Pre-Fair effluent samples obtained at Pleasanton.

In summary, over the ranges of the effluent microbiological group concentrations obtained during the Pre-Fair sampling at Pleasanton (from one order of magnitude for coliphage and total coliform to well over two orders of magnitude for *Pseudomonas* and *Clostridium perfringens*), there are only the most tenuous of relationships between some pathogenic parameters and some indicator parameters. These relationships are certainly an insufficient basis for discontinuing the pathogenic analyses of the effluent samples in later phases of the study.

f. Microbial Characterization

A thorough characterization of the treated sewage effluent at the Pleasanton site was conducted to identify the types of pathogenic bacteria and viruses. Few pathogenic organisms were isolated, despite the detection of relatively high levels of indicator bacteria in effluent and aerosol samples. The analytical methods employed in the present study were designed to provide definitive information on the types and approximate quantities of the bacterial population (including non-pathogens, opportunistic pathogens, and overt pathogens) present in the sewage effluent.

The levels of the routinely-assessed microorganism groups are given in Table VI. A-18 for

Table VI.A-17.

CANONICAL CORRELATION OF THE PATHOGEN EFFLUENT CONCENTRATION SET WITH THE INDICATOR EFFLUENT CONCENTRATION SET

Pair	Eigenvalue	Canonical Correlation	Wilk's Lambda	Significance of Canonical Correlation
1	0.407	0.638	0.354	P = 0.041
2	0.298	0.538	0.597	P = 0.191
3	0.121	0.348	0.840	P = 0.491

Coefficients of Significant Canonical Variables ($P < 0.05$)

	Pair 1
Indicator Set	
Ln X_{TC_e}	-0.623
LN X_{FC_e}	-0.475
Ln X_{PC_e}	0.679
Ln X_{CP_e}	0.162
Pathogen Set	
Ln X_{PS_e}	-0.045
Ln X_{ST_e}	-0.422
Ln X_{CL_e}	-0.113
Ln X_{V3_e}	-0.313
Ln X_{V5_e}	0.968

Table VI.A-18.

EFFLUENT CONCENTRATIONS OF USUAL MICROBIOLOGICAL CONSTITUENTS IN LARGE-VOLUME SAMPLES TAKEN FOR MICROBIAL CHARACTERIZATION

Sample Date	Total Coliform (MF C/100 ml) × 10[illegible]	Fecal Coliform (MF C/100 ml) × 10[illegible]	Standard Plate Count (No./100 ml) × 10[illegible]	Coliphage (PFU/l) × 10[illegible]	Klebsiella (CFU/100 ml) × 10[illegible]	Pseudomonas (CFU/100 ml) × 10[illegible]	Streptococci (CFU/100 ml) × 10[illegible]	Clostridium perfringens (MPN/100 ml) × 10[illegible]	3-Day Plaques (PFU/l)	5-Day Plaques (PFU/l)
4-29-76	630	56	80	210	CS	CS	CS	CS	244*	26.2*
5-5-76	1110	150	100	500	6.1	300	CS	11	40	28
5-13-76	240	27	40	260	66	120	9.3†	0.41	15	27
5-21-76	1900	115	6.1	490	88	300	18	11	7.2	13
5-26-76	2000	250	260	80	22	1000	23	11	1.8	2.5
6-1-76	1100	168	6.1	510	50	310	26	4.3	18	CS
6-22-76	473	85	11	190	6.9	120	5.1	7.5		

*Possible contamination

†Most probable number

M: Missing value

CS: Contaminated sample

the seven large-volume effluent samples taken for microbial characterization during Pre-Fair. These levels are representative of those obtained for the daily composite effluent samples.

A summary of all other bacterial types identified in these large-volume effluent samples is presented in Table VI. A-19. Data from the first large-volume sample and portions of the data from the second and third large-volume samples could not be obtained. These samples were received before the various differential and selective plating and diagnostic media required for the respective analyses were available. Large-volume samples obtained, on 5-21, 5-24, 6-1, 6-22, and 11-29, 1976 were characterized for every bacterial type or group listed, according to the procedures described in Appendix D, Methods and Materials. In addition, three of the daily composite effluent samples from Pre-Fair (i.e. sample dates 6-15, 6-16, and 6-17, 1976) were subjected to the same rigorous analyses. This provides additional data for comporison of the bacterial populations in the two types of effluent samples. It should be noted that the data from the microbial characterization of the aggregated large-volume aerosol sample (discussed as run M1-36 in Section VI.B.6) are also presented for comparison.

The data show that the components of the bacterial populations of the large volume (grab) and daily composite samples examined were qualitatively similar. Inspection of the quantitative data obtained for the selected microbial parameters (*Klebsiella*, *Pseudomonas*, fecal streptococci, and *Clostridium perfringens*) (Table VI.A-18) in the two types of effluent samples also suggests similarity. The approximate numbers of other bacterial types isolated from both types of samples were not appreciably different, with the exception of the isolation of *Leptospira*, *Salmonella*, and *Shigella* only from the large-volume samples. However, this observation may be a reflection of the small number of samples examined.

The small number of *Staphylococcus aureus* isolated from the effluent samples was surprising. Four of the eight large-volume and all of the daily composite samples plated to Mannitol Salt Agar were positive for this organism. Only the lowest dilution plates (0.1 mL) yielded numerous colonies, most of which were *Micrococcaceae*. The maximal number of the latter which proved to be *Staphylococcus aureus* was 40 cfu/ml in the composite for 6-16. In contrast, large numbers of colonies grew on the selective medium for Neisseria at 10^{-2} dilutions of the effluent samples. However, none of the representative colony types picked proved to be *Neisseria gonorrheae* or *Neisseria meningitidis*. Enrichment for *Leptospira* was positive in four of five large-volume samples but not the three daily composite samples examined. The negative results in the latter may be the result of lack of sensitivity of the test system employed. Enrichment tubes showing turbidity were examined by dark field microscopy. Failure to observe an organism with typical *Leptospira* morphology and motility in one of at least 15 randomly-selected fields constituted a negative test. However, only a very small fraction of an enrichment is examined when this is carried out microscopically, a fact complicated by the wet mounts required for dark field. Thus, positive enrichment tubes with light growth of *Leptospira* may not be detected. Of the positive samples, enrichment tubes from the large-volume sample of 5-24 yielded the greatest number of "typical" *Leptospira* (40/15 microscopic fields).

The genus *Mycobacterium* includes species that range from saprophytes widely distributed in soil and water to facultative and obligate intracellular parasites. Positive isolation of mycobacteria from effluent samples was expected. However, the large number of these organisms (approximately 10 CFU/mL) in every large-volume and daily composite sample examined was surprising. Isolation and identification of these organisms was facilitated by the treatment procedure which resulted in plates that were relatively free of other organisms. None of the isolates of the various colony types that were carried through the identification scheme (Figure III.B-2 in Appendix D) proved to be *Mycobacterium tuberculosis*. However, representatives of the following groups or species were identified: *Mycobacterium ulcerans*, *Mycobacterium gordanae*, Runyon Group I, Runyon Group II, Runyon Group III, *Mycobacterium marinum*, Runyon Group IV. A single confirmed *Mycobacterium ulcerans* was the only *Mycobacterium* isolated that is a pathogen of the same cat-

Table VI.A-19.
SUMMARY OF BACTERIAL IDENTIFIED—LARGE-VOLUME SAMPLES

							Gram Neg. Non-Fermenters				Enterobacteriaceae												
Waste-water Sample Date	*Clostridium perfringens*	Fecal Streptococci	*Staphylococcus aureus*	*Leptospira*	*Mycobacteria*	*Neisseria* (pathogenic species)	Fluorescent Pseudomonads	Other Oxidase Pos. Glucose Oxidizers	*Alcaligenes* and Other Oxid. Pos. Glucose Inactive	*Acinetobacter* and Other Oxid. Neg.	*Klebsiella*	*Enterobacter*	*Serratia*	*Edwardsiella*	*Escherichia*	*Shigella*	*Salmonella*	*Arizona*	*Citrobacter*	*Proteus*	*Providencia*	*Yersinia*	*Aeromonas* and Other Oxid. Pos. Fermenters
5-5-76	X	•	•	•	•	•	X	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
5-13-76	X	X	X	X	•		X	X	X	X	•	•	•	•	•	•	•	•	•	•	•	•	X
5-21-76	X	X		X	X		X	X	X	X	X	X			X	X					X		X
5-24-76	X	X		X	X		X	X			X	X	X		X	X			X	X			X
6-1-76	X	X		X	X		X		X		X	X	X		X				X	X			X
6-22-76	X	X	X		X		X	X	X		X	X			X	X	X		X	X			X
Aerosol (run #35)	X	X	X		X		X			X	X	X			X					X			X
6-16-76	X	X			•		X	X	X		X	X	X		X				X	X			X
6-17-76	X	X	X		X		X	X	X		X	X			X				X	X			X
6-18-76	X	X	X		X		X	X	X		X	X	X		X					X			X

NOTES: X - Positive isolations; blank indicates none detected; • - assay not run.

egory as *Mycobacterium tuberculosis*[23]. Others range from usually pathogenic (*Mycobacterium marinum*) to usually nonpathogenic.

The distribution of the various groups of Gram-negative nonfermenting organisms, the genera of *Enterobacteriaceae*, and the oxidase positive fermenting organisms was determined by characterization of colonies picked from moderately to highly selective enteric plating media (Tables VI. A-19 and VI. A-20). A different pattern, with a better representation of the coliforms, would probably have been obtained by extensive isolation and characterization of colonies from the nonselective media EMB, ENDO, and MacConkeys. However, the possibility of enhancing the frequency of isolation of the major enteric pathogens was desired. As illustrated in Table VI. A-20, 79 percent of the isolates from the direct platings on selective media were oxidase positive. The majority of these organisms (49 percent) were fermenters which would have been incorrectly identified as various genera of *Enterobacteriaceae* if the oxidase test had not been employed. In contrast, 82 percent of isolates picked from the selective media following enrichment in GN, selenite, or tetrathionate broths were *Enterobacteriaceae*.

The distribution of the various species of *Enterobacteriaceae* observed in the large-volume and daily composite effluent samples is summarized in Table VI. A-21. The data for the aggregated aerosol sample are shown for comparison. Isolates of both *Salmonella* and *Shigella* were detected only in large-volume sample obtained on 6-22-76. When the data are taken as a whole, most of the species were represented in, at least, one of the effluent samples. Table VI. A-22 is an analysis of the percentage of each species of *Enterobacteriaceae* isolated from the total of direct platings and enrichments of the large-volume samples. It should be noted that the enrichment procedure for *Yersinia enterocolitica* (an organism increasingly implicated in enterocolitis and mesenteric lymphadenitis) failed to yield a single isolate of this organism. The few colonies which appeared on the plating media were predominantly oxidase-positive Gram-negative fermenters. How-

Table VI.A-20.
GROUPS OF ORGANISMS FROM DIRECT PLATINGS AND ENRICHMENTS FOR ENTERICS
Large-Volume Samples

Group	% Isolates Direct Plating on XLD, HEK, BS, SS	% Isolates From Enrichments
All Enterobacteriaceae	19	82
Fluorescent Pseudomonads	14	6
Non-Fermenting, Oxidase Positive Glucose Oxidizers*	9	2
Alcaligenes and Other Oxidase Positive Glucose Inactive	9	1
Acinetobacter and Other Oxidase Negative Non-Fermenters	2	1
Aeromonas and Other Oxidase Positive Fermenters	47	8

* Other than fluorescent pseudomonads.

Table VI.A-21.
SPECIES OF ENTEROBACTERIACEAE IDENTIFIED—LARGE VOLUME AEROSOL SAMPLES

Waste-water Sample Date	Klebsiella pneumoniae	Klebsiella ozaenae	Klebsiella rhinoschleromatis	Enterobacter cloacae	Enterobacter aerogenes	Enterobacter hafniae	Aerogenic Ent. agglomerans	Anaerogenic Ent. agglomerans	Serratia marcescens	Serratia liquefaciens	Serratia rubidaea	Edwardsiella tarda	Escherichia coli	Escherichia coli A-D	Shigella (all species)	Salmonella (all species)	Arizona (Sal. arizonae)	Citrobacter freundii	Citrobacter diversus	Proteus vulgaris	Proteus mirabilis	Proteus morganii	Proteus rettgeri	Providencia alcalifaciens	Providencia stuartii	Yersinia enterocolitica	Yersinia pseudotuberculosis
5-5-76	X			X			X						X		X									X			
5-13-76	X						X	X			X		X		X			X		X	X	X	X				
5-21-76	X			X	X		X			X			X					X	X	X	X	X					
6-1-76	X	X		X	X		X						X		X	X		X			X	X					
Aerosol (run #36)	X			X			X	X					X									X					
6-16-76	X			X					X	X			X					X			X						
6-17-76	X	X		X			X	X					X					X			X						
6-13-76	X					X	X	X		X			X								X						

NOTES: X - Positive isolations; blank indicates none detected.

ever, a *Yersinia pseudotuberculosis* isolate and a *Shigella* isolate were identified from separate aerosol samples during a routine pick of colonies.

At the beginning of Post-Fair, a large volume sample was taken and analyzed by semi-quantitative procedures. The results of this microbiological screen are presented in Table VI. A-23.

g. *Respiratory Virus*

Five roller tubes showing viral cytopathology were subcultured successfully, indicating confirmation as viruses. The viruses from four of these five tubes were typed as ECHO 6. The virus in the other tube remains unidentified, since typing was unsuccessful.

Thirty-five (35) roller tubes survived uncontaminated through primary subculture without showing viral cytopathology. All subcultures were challenged with ECHO 11 for rubella. All showed typical ECHO 11 cytopathology and were reported as negative for rubella. Fluids from all subcultures were inoculated into four 10-day embryonated checken eggs, inculbated 72 hours and the allantoic fluids harvested and tested for hemagglutinins against crbc; all were negative. The control influenza strain gave 1:16 HA.

Table VI.A-22.
ANALYSIS OF ENTEROBACTERIACEAE
(Percent of Each Species Isolated From Total of Direct Platings and Enrichments— Large Volume Samples of 5-21-76, 5-24-76, 6-1-76, 6-22-76)
Excluding *E. coli**

	Percent		Percent
K. pneumoniae	9.2	Arizona	0
K. ozaenae	1.5		
K. rhinoscheromatis	0	*C. freundii*	16.0
		C. diversus	1.5
E. cloacae	11.4		
E. aerogenes	1.5	*P. vulgaris*	3.8
E. hafniae	0.8	*P. mirabilis*	16.8
E. agglomerans (aerogenic)	14.5	*P. morganii*	3.1
E. agglomerans (anaerogenic)	3.1	*P. rettgeri*	2.3
S. marcescens	0.8	*P. alcalifaciens*	0.8
S. liquefaciens	2.3	*P. stuartii*	0
S. rubidaea	0.8		
		Y. enterocolitica	0
E. tarda	0	*Y. pseudotuberculosis*	0
Shigella (all species)	3.1	Unidentified	6.1
Salmonella (all species)	0.8		

**E. coli* was the predominant representative of the Enterobacteriaceae. Values are the percentage from direct platings on XLD, Hektoen, SS, and BS agars and from enrichments in GN, tetrathionate, and selenite broths.

Table VI.A-23.
SEMI-QUANTITATIVE MICROBIOLOGICAL SCREEN OF POST-FAIR SAMPLE (11-29-76)

Bacteria:	cfu/100ml	
Arizona	$<3.0x10^3$	(ND)
Citrobacter freundii	$1.0x10^5$	
Edwardsiella	$<3.0x10^3$	(ND)
Enterobacter aerogenes	$1.0x10^4$	
Enterobacter cloacae	$3.0x10^6$	
Escherichia H_2S^+	$1.0x10^5$	
Fecal Coliform	$2.2x10^4$	
Fecal Streptococci	$1.7x10^3$	
Klebsiella pneumoniae	$7.0x10^4$	
Klebsiella ozaenae	$4.0x10^4$	
Mycobacteria	$1.4x10^4$	
Proteus	$<3.0x10^3$	(ND)
Providencia	$<3.0x10^3$	(ND)
Pseudomonas	$2.0x10^4$	
Salmonella	$<3.0x10^3$	(ND)
Serratia	$<3.0x10^3$	(ND)
Shigella	$<3.0x10^3$	(ND)
Staphylococcus	$4.0x10^3$	
Total coliform	$1.2x10^6$	
Total Plate Count	$1.5x10^7$	
Yersinia	*	(ND)
Of the total number of colonies which were randomly picked and biochemically tested for Enterobacteriaceaa:		
Oxidae positive	46.5%	
Klebsiella ozaenae	6.9%	
Klebsiella pneumonia	13.9%	
Enterobacter cloacae	13.9%	
Enterobacter aerogenes	1.1%	
Escherichia H_2S^+	2.3%	
Citrobacter freundii	5.8%	
No growth	9.3%	
Viruses:		
Coliphage	$4.8x10^5$	pfu/l
Enteroviruses 3day	161	pfu/l
5day	242	pfu/l
Concentration Efficiency	100%	
Total Organic Carbon:		
Filtered	33	mg/l
Unfiltered	39	mg/l

Note: ND - none detected
* - nonquantitative procedure

B. Aerosol Run Data Characteristics

1. Meteorological and Sampling Conditions

a. *Meteorological Conditions*

Thirty-six microbiological aerosol runs were attempted during the Pre-Fair sampling period. Five of the aerosol runs were quality assurance runs. Eleven aerosol runs had to be aborted because wind shifts violated one or more of the aerosol run criteria specified in the aerosol sampling protocol (see Appendix D). The 20 remaining aerosol sampling runs all met the protocol criteria. In addition to the microbiological aerosol runs, seven dye aerosol runs were successfully completed during the Pre-Fair sampling period. The environmental conditions during both the microbiological and dye aerosol runs appear in Table VI.B-1.

Table VI.B-1.
AEROSOL RUN METEOROLOGICAL AND SOURCE DATA SUMMARY
a. Temperature and Relative Humidity

Aerosol Runs			Air Temperature, °C				Relative Humidity, %					Wastewater Temperature, °C
Run No.	Run Date	Time of Run	2m at Effluent Pond	2m at Met. Tower	Just Upwind of Spray Line	Just Downwind of (Within) Spray Line	2m at Effluent Pond	2m at Met. Tower	Livermore	Just Upwind of Spray Line	Just Downwind of (Within) Spray Line	
Dye Aerosol Runs												
Pre-Fair												
D1-1	5-4-76	1355-1405	19.4	(19.4)	(19.9)	(18.3)	71	(39)	39	(54)	(59)	(21.7)
D1-3	5-28-76	1555-1625	18.3	(18.3)	(19.0)	(17.5)	(70)	(22)	22	(37)	(44)	(23.8)
D1-4	5-31-76	2030-2100	14.4	(14.4)	(15.8)	(14.7)	71	(40)	40	(55)	(60)	(22.7)
D1-5	5-31-76	2126-2156	13.3	(13.3)	(14.9)	(13.9)	72	(76)	76	(91)	(92)	(22.4)
D1-6	6-1-76	1805-1835	21.1	(21.1)	(21.3)	(19.5)	65	(24)	24	(39)	(46)	(23.5)
D1-9	6-14-76	1740-1810	33.9	(33.9)	(31.8)	(28.9)	45	(5)	5	(20)	(29)	28.0
D1-10	6-16-76	1640-1710	31.7	(31.7)	(30.0)	(27.3)	60	(19)	19	(34)	(41)	28.0
Post-Fair												
D2-1	12-2-76	1435-1505	16.7	16.1	18.3	15.0	(74)	31	(31)	51	59	16.0
D2-2	12-5-76	1253-1323	19.4	20.0	20.0	14.4	(70)	20	(20)	26	55	16.0
D2-4	12-6-76	1345-1415	15.6	16.1	22.8	17.2	(74)	31	54	53	65	15.5
D2-5	12-6-76	1520-1550	13.9	14.4	21.1	16.1	(77)	36	54	56	66	15.5
D2-6	12-6-76	1523-1553	18.9	18.3	20.6	14.4	63	23	31	23	38	14.0
D2-7	12-16-76	1303-1330	12.8	14.4	18.3	16.1	80	48	46	45	53	15.0
D2-8	12-16-76	1347-1417	13.3	14.4	18.3	16.1	79	48	47	45	53	15.0
D2-9	1-13-76	1312-1342	5.6	7.2	8.9	(8.3)	96	78	68	72	75	12.0
D2-10	1-13-76	1400-1430	4.4	7.2	8.3	7.8	96	78	73	83	83	12.0
D2-11	1-13-76	1835-1905	4.4	6.7	5.6	5.0	96	80	74	100	100	(11.5)
Microbiological Aerosol Runs												
Pre-Fair												
M1-1	5-4-77	1547-1617	21.1	(21.1)	(21.3)	(19.5)	72	(44)	44	(59)	(64)	(21.7)
M1-2	5-5-77	1538-1608	18.9	(18.9)	(19.5)	(17.9)	72	(38)	38	(53)	(58)	(21.7)
M1-3	5-5-77	1700-1730	18.3	(18.3)	(19.0)	(17.5)	71	(40)	40	(55)	(60)	(21.3)
M1-4	5-13-76	1525-1655	35.0	(35.0)	(32.7)	(29.7)	52	(12)	12	(27)	(32)	(22.3)
M1-5	5-13-76	1807-1837	32.2	(32.2)	(30.4)	(27.6)	52	(9)	9	(24)	(29)	(21.8)
M1-6	5-17-76	1923-1953	13.9	(13.9)	(15.4)	(14.3)	65	(85)	85	(100)	(100)	(21.7)
M1-7	5-17-76	2044-2114	10.0	(10.0)	(12.2)	(11.5)	75	(60)	60	(75)	(80)	(21.3)
M1-8	5-21-76	1538-1608	23.3	(23.0)	(23.1)	(21.1)	65	(32)	32	(47)	(52)	(23.2)
M1-9	5-24-76	1557-1627	17.2	(17.2)	(18.1)	(16.7)	76	(45)	45	(60)	(65)	(23.3)

NOTE: Values in parentheses have been substituted according to criteria described in the text.

Table VI.B-1. (cont'd)

Aerosol Runs			Air Temperature, °C				Relative Humidity, %					
Run No.	Run Date	Time of Run	2m at Effluent Pond	2m at Met. Tower	Just Upwind of Spray Line	Just Downwind of (Within) Spray Line	2m at Effluent Pond	2m at Met. Tower	Livermore	Just Upwind of Spray Line	Just Downwind of (Within) Spray Line	Wastewater Temperature, °C
Microbiological Aerosol Runs (cont'd)												
Pre-Fair (cont'd)												
M1-10	5-24-76	2032-2102	12.2	(12.2)	(14.0)	(13.1)	83	(86)	86	(100)	(100)	(22.0)
M1-11	5-25-76	2214-2244	15.6	(15.6)	(16.8)	(15.5)	71	(37)	37	(52)	(57)	(21.6)
M1-12	5-27-76	1717-1747	16.7	(16.7)	(17.7)	(16.3)	76	(46)	46	(61)	(66)	24.0
M1-13	5-27-76	2040-2110	10.6	(10.6)	(12.7)	(11.9)	80	(75)	75	(90)	(95)	24.0
M1-14	5-27-76	2150-2220	10.0	(10.0)	(12.2)	(11.5)	84	(80)	80	(95)	(100)	24.0
M1-15	6-3-76	2117-2147	10.0	(10.0)	(12.2)	(11.5)	76	(64)	64	(79)	(84)	(22.6)
M1-31	6-14-76	2010-2040	28.3	(28.3)	(27.2)	(24.8)	47	(5)	5	(20)	(25)	24.0
M1-32	6-15-76	1420-1450	37.2	(37.2)	(34.5)	(31.3)	50	(6)	6	(21)	(26)	26.0
M1-33	6-15-76	1635-1705	33.9	(33.9)	(31.8)	(28.9)	50	(20)	20	(35)	(40)	28.0
M1-34	6-16-76	2140-2210	21.1	(21.1)	(21.3)	(19.5)	65	(45)	45	(60)	(65)	(23.7)
M1-35	6-17-76	2242-2312	15.6	(15.6	(16.8)	(15.5)	77	(65)	65	(80)	(85)	26.0
Post-Fair												
M2-1	1-21-77	1600-1630	10.6	13.3	12.8	12.2	90	78	69	74	82	15.3
M2-2	1-25-77	1415-1445	10.0	12.1	13.3	12.2	87	75	60	82	82	15.9
M2-3	1-25-77	2012-2042	5.6	8.9	8.9	8.9	98	84	83	88	91	13.6
M2-4	1-30-77	1421-1451	(8.7)	9.7	10.0	10.0	91	69	57	77	79	13.3
M2-5	1-30-77	1603-1633	(8.5)	9.5	10.0	10.0	92	71	46	82	82	13.3
M2-6	2-9-77	1353-1423	13.3	15.0	14.4	14.4	87	72	(72)	71	78	15.5
M2-10	2-23-77	1835-1905	8.4	9.4	8.1	8.9	80	50	65	96	96	14.0
M2-11	2-24-77	1403-1433	11.7	13.3	13.9	13.9	74	35	45	48	53	16.2
M2-12	2-24-77	1513-1543	11.5	13.5	13.9	13.9	72	31	33	45	45	16.2
M2-13	2-28-77	2003-2033	5.6	7.8	(8.6)	(8.3)	87	55	69	(70)	(75)	15.6
M2-14	3-14-77	1625-1655	10.6	11.4	11.9	11.9	76	42	48	51	51	17.5
M2-15	3-16-77	1555-1625	9.4	10.0	12.2	11.4	88	52	62	59	63	17.3
M2-16	3-17-77	1616-1646	10.6	11.6	12.2	11.4	85	48	64	64	66	17.3
M2-17	3-18-77	1620-1650	10.6	18.9	13.9	13.6	78	27	33	54	56	17.6
M2-22	3-25-77	1344-1414	15.0	16.7	16.4	16.1	78	33	41	43	52	17.6
M2-23	3-26-77	1315-1345	19.4	20.6	20.0	18.9	69	21	24	35	40	17.9
M2-24	3-26-77	1634-1704	20.0	19.5	18.9	18.3	70	29	24	44	50	18.0
M2-25	3-27-77	1330-1400	17.2	17.8	17.5	17.5	79	36	53	63	65	17.8
M2-26	3-27-77	1518-1548	16.7	16.1	16.1	16.4	78	39	51	62	60	18.0
M2-29	4-11-77	1515-1545	22.2	21.7	21.9	21.1	75	29	38	31	38	19.8

Table VI.B-1. (cont'd)

Aerosol Runs			Air Temperature, °C				Relative Humidity, %					Wastewater Temperature, °C
Run No.	Run Date	Time of Run	2m at Effluent Pond	2m at Met. Tower	Just Upwind of Spray Line	Just Downwind of (Within) Spray Line	2m at Effluent Pond	2m at Met. Tower	Livermore	Just Upwind of Spray Line	Just Downwind of (Within) Spray Line	
Microbiological Aerosol Runs (cont'd)												
Post-Fair (cont'd)												
M2-30	4-12-77	1615-1645	22.8	23.3	21.9	21.4	69	21	28	17	19	19.8
M2-31	4-13-77	2106-2135	8.9	10.0	8.1	8.3	91	52	82	63	80	19.5
M2-32	4-14-77	2010-2040	(13.3)	13.3	10.8	11.4	(77)	37	55	65	66	18.0
M2-33	4-19-77	1640-1710	21.7	22.8	21.7	20.8	68	16	16	29	33	19.9
M2-34	4-19-77	2050-2120	15.6	13.3	11.4	11.7	68	25	21	43	44	19.4
M2-35	4-22-77	1410-1440	(26.7)	26.7	24.4	23.9	(65)	9	20	23	28	19.6
M2-36	4-23-77	1630-1700	(24.4)	24.4	23.3	22.5	(68)	15	22	26	29	19.9
M2-37	4-24-77	1335-1405	21.7	22.5	20.3	19.4	73	30	36	39	45	19.7
M2-38	4-24-77	1505-1535	18.9	19.5	18.9	17.5	74	23	32	36	45	19.6
Quality Assurance Aerosol Runs												
Pre-Fair												
M1-16-19	6-7-76	2104-2134	10.0	(10.0)	(12.2)	(11.5)	81	(74)	74	(89)	(94)	(23.0)
M1-20-23	6-8-76	1750-1820	18.3	(18.3)	(19.0)	(17.5)	64	(40)	40	(55)	(60)	17.0
M1-24-25	6-9-76	2259-2329	11.1	(11.1)	(13.1)	(12.3)	82	(70)	70	(85)	(90)	21.0
M1-26	6-10-76	2212-2242	11.1	(11.1)	(13.1)	(12.3)	84	(64)	64	(79)	(84)	22.0
M1-27-30	6-13-76	1707-1737	27.8	(27.8)	(26.8)	(24.4)	57	(9)	9	(24)	(29)	27.0
Post-Fair												
M2-8-9	2-16-77	1805-1835	17.2	16.7	(18.1)	(16.7)	78	58	51	73	(76)	17.8
M2-27-28	4-5-77	1635-1709	23.3	22.8	23.3	22.8	72	25	32	18	21	20.3
Virus Aerosol Runs												
Post-Fair												
V2-I.1	2-25-77	1753-1823	(11.1)	11.1			77	47		(62)		15.5
V2-I.3	2-26-77	1505-1535	(16.7)	16.7			70	36		(51)		16.8
V2-I.4	2-26-77	1545-1615	(16.7)	16.7			70	37		(52)		16.5
V2-I.5	2-26-77	1624-1654	(15.6)	15.6			72	36		(51)		16.3
V2-I.6	2-26-77	1703-1733	(14.4)	14.4			73	45		(60)		15.3
V2-II.1	4-9-77	1450-1520	(16.1)	16.1	16.1	15.8	78	35	41	55	59	19.5

Table VI.B-1. (cont'd)

Aerosol Runs			Air Temperature, °C				Relative Humidity, %					Wastewater Temperature, °C
Run No.	Run Date	Time of Run	2m at Effluent Pond	2m at Met. Tower	Just Upwind of Spray Line	Just Downwind of (Within) Spray Line	2m at Effluent Pond	2m at Met. Tower	Livermore	Just Upwind of Spray Line	Just Downwind of (Within) Spray Line	
Virus Aerosol Runs (cont'd)												
Post-Fair (cont'd)												
V2-II.2	4-9-77	1530-1600	(16.1)	16.1	15.8	15.5	78	35	41	54	59	19.3
V2-II.3	4-9-77	1610-1640	(15.0)	15.0	15.0	14.4	78	38	41	56	63	19.2
V2-II.4	4-9-77	1655-1725	(14.4)	14.4	14.2	13.6	79	38	41	60	61	19.2
V2-II.5	4-9-77	1735-1805	(13.3)	13.3	13.9	13.3	80	40	41	59	61	19.2
V2-II.6	4-9-77	1815-1845	(12.1)	12.1	11.7	11.7	81	44	41	66	66	19.0

Table VI.B-1.
AEROSOL RUN METEOROLOGICAL AND SOURCE DATA SUMMARY
b. Wind Direction, Velocity, Stability and Solar Radiation

Aerosol Runs			Mean Wind Direction, deg		Wind Velocity, m/sec			Radiation				Wind Stability		
Run No.	Run Date	Time of Run	Relative to True North	Relative to Perpendicular to Spray Line	10m at Effluent Pond	4m at Met. Tower	2m in Spray Field	Cloud Cover in Eighths	Cloud Height, m	Net Radiation Index	Solar Radiation W/m²	Azimuth St. Dev. σ_A' (rad.)	Elevation St. Dev. σ_E' (rad.)	Pasquill Stability Class
Dye Aerosol Runs														
Pre-Fair														
D1-1	5-4-76	1355-1405	260	−40	8.9	(8.2)	(8.2)	4	High	4	(930)	0.24	0.052	3
D1-3	5-28-76	1555-1625	250	−30	6.0	(5.1)	(5.1)	<1		3	(800)	0.18	0.065	3
D1-4	5-31-76	2030-2100	250	−30	2.3	(1.5)	(1.5)	<1		−2	(17)	0.48	0.051	7
D1-5	5-31-76	2126-2156	220	0	1.8	(1.2)	(1.2)	<1		−2	(17)	0.38	0.051	7
D1-6	6-1-76	1805-1835	255	−35	2.1	(1.5)	(1.5)	5		1	(340)	0.45	0.065	3
D1-9	6-14-76	1740-1810	20	+20	2.3	(1.8)	(1.8)	<1		2	(520)	0.42	0.093	2
D1-10	6-16-76	1640-1710	261	−41	6.7	(5.1)	(5.1)	<1		3	(710)	0.18	0.065	3
Post-Fair														
D2-1	12-2-76	1435-1505	101	−61	1.1	2.0	1.1	0	Haze	2	290	0.23	0.093	3
D2-2	12-5-76	1253-1323	41	−1	4.1	4.1	3.6	1	High	2	430	0.24	0.075	3
D2-4	12-6-76	1345-1415	97	−37	4.3	2.8	1.8	0	Haze	2	410	0.30	0.093	3
D2-5	12-6-76	1520-1550	68	−28	4,0	3.1	2.2	0	Haze	1	105	0.21	0.052	4
D2-6	12-6-76	1523-1553	74	−34	3.8	3.3	3.1	0	Haze	1	170	0.10	0.052	4
D2-7	12-16-76	1303-1333	57	−17	2.9	2.8	1.8	0	Haze	2	(510)	0.27	0.093	3
D2-8	12-16-76	1347-1417	74	−34	3.6	2.5	1.6	0	Haze	2	(450)	0.28	0.093	3
D2-9	1-13-77	1312-1342	59	−19	3.7	2.8	1.8	8	Low	1	180	0.26	0.052	4
D2-10	1-13-77	1400-1430	66	−26	4.5	3.6	3.1	8	Low	1	126	0.16	0.052	4
D2-11	1-13-77	1835-1905	66	−26	2.9	2.1	1.1	8	150	−1	35	0.25	0.051	5
Microbiological Aerosol Runs														
Pre-Fair														
M1-1	5-4-77	1547-1617	290	−70	5.1	(4.3)	4.3	2		3	(730)	0.49	0.065	3
M1-2	5-5-77	1538-1608	260	−40	4.7	(3.7)	3.7	3		3	(750)	0.21	0.093	2
M1-3	5-5-77	1700-1730	275	−55	3.0	(2.3)	2.3	4		2	(570)	0.31	0.075	3
M1-4	5-13-76	1625-1655	265	−45	5.9	(5.0)	5.0	0		3	(700)	0.21	0.065	3
M1-5	5-13-76	1807-1837	240	−20	2.5	(1.8)	1.8	0		2	(370)	0.59	0.093	2
M1-6	5-17-76	1923-1953	175	+45	5.7	(4.5)	4.5	0		1	(112)	0.21	0.047	4
M1-7	5-17-76	2044-2114	145	+75	5.4	(4.2)	4.2	0		−2	(17)	0.28	0.038	5
M1-8	5-21-76	1538-1608	275	−55	3.2	(2.5)	2.5	0	Haze	3	(840)	0.63	0.093	2
M1-9	5-24-76	1557-1627	251	−31	5.4	(4.6)	4.6	1	Low	3	(750)	0.35	0.065	3
M1-10	5-24-76	2032-2102	215	+5	5.5	(4.3)	4.3	1	Low	−2	(17)	0.38	0.038	5

Table VI.B-1. (cont'd)

Aerosol Runs			Mean Wind Direction, deg		Wind Velocity, m/sec			Radiation				Wind Stability		
Run No.	Run Date	Time of Run	Relative to True North	Relative to Perpendicular to Spray Line	10m at Effluent Pond	4m at Met. Tower	2m in Spray Field	Cloud Cover in Eighths	Cloud Height, m	Net Radiation Index	Solar Radiation, W/m²	Azimuth St. Dev. σ_A (rad.)	Elevation St. Dev. σ_E (rad.)	Pasquill Stability Class
Microbiological Aerosol Runs (cont'd)														
Pre-Fair (cont'd)														
M1-11	5-25-76	2214-2244	210	+10	1.6	(1.1)	1.1	0		–2	(17)	0.21	0.051	7
M1-12	5-27-76	1717-1747	180	+40	4.8	(3.7)	3.7	1		2	(560)	0.52	0.075	3
M1-13	5-27-76	2040-2110	200	+20	8.7	(6.8)	6.8	1		–2	(17)	0.18	0.038	4
M1-14	5-27-76	2150-2220	210	+10	4.5	(3.3)	3.3	<1		–2	(17)	0.45	0.045	6
M1-15	6-3-76	2117-2147	188	+32	3.9	(1.1)	1.1	<1		–2	(17)	0.31	0.045	7
M1-31	6-14-76	2010-2040	150	+70	1.8	(0.5)	0.5	<1		1	(17)	1.01	0.065	3
M1-32	6-15-76	1420-1450	265	–45	4.5	(3.8)	3.8	3		4	(900)	0.28	0.110	2
M1-33	6-15-76	1635-1705	275	–55	6.9	(5.6)	5.6	3		3	(670)	0.31	0.065	3
M1-34	6-16-76	2140-2210	230	–10	3.0	(0.9)	0.9	<1		–2	(17)	0.28	0.045	7
M1-35	6-17-76	2242-2312	35	+5	3.1	(1.1)	1.1	<1		–2	(17)	0.31	0.045	7
Post-Fair														
M2-1	1-21-77	1600-1630	72	–32	1.3	1.7	1.3	7	Low	1	180	0.18	0.065	3
M2-2	1-25-77	1415-1445	87	–47	5.1	2.5	3.1	7	Low	0	430	0.35	0.056	4
M2-3	1-25-77	2012-2042	68	–28	3.0	1.9	2.0	0		–1	21	0.14	0.051	5
M2-4	1-30-77	1421-1451	68	–28	(2.3)	2.0	2.0	1	Haze	2	370	0.22	0.093	3
M2-5	1-30-77	1603-1633	68	–28	(2.3)	2.0	2.0	3	Haze	1	70	0.22	0.065	4
M2-6	2-9-77	1853-1423	159	+61	1.9	2.0	1.3	6		1	260	0.14	0.065	4
M2-10	2-23-77	1835-1905	239	–19	1.6	2.7	1.8	8	High	–1	0	0.26	0.051	5
M2-11	2-24-77	1403-1433	78	+38	1.8	4.2	3.1	7	7000	2	660	0.33	0.051	3
M2-12	2-24-77	1513-1543	75	+35	4.6	4.1	3.4	6	7000	1	540	0.28	0.075	4
M2-13	2-28-77	2003-2033	285	–65	1.7	3.6	2.2	0		–2	35	0.26	0.052	5
M2-14	3-14-77	1625-1655	229	–9	2.8	3.2	1.6	7	1900	1	112	0.30	0.045	4
M2-15	3-16-77	1555-1625	289	–69	3.4	4.7	3.6	4	1500	1	560	0.30	0.052	4
M2-16	3-17-77	1616-1646	65	+25	4.1	4.5	4.9	0	1800	2	370	0.44	0.075	3
M2-17	3-18-77	1620-1650	266	–46	4.5	6.0	4.5	<1	1200	2	300	0.18	0.065	4
M2-22	3-25-77	1344-1414	99	+59	6.0	5.6	4.9	<1	1500	4	840	0.27	0.082	3
M2-23	3-26-77	1315-1345	86	+46	3.6	3.7	2.7	0	Haze	4	870	0.38	0.101	2
M2-24	3-26-77	1634-1704	274	–54	2.4	4.4	3.4	<1	Haze	2	430	0.17	0.075	3
M2-25	3-27-77	1330-1400	270	–50	6.3	6.2	5.4	0	9100	4	890	0.25	0.082	3
M2-26	3-27-77	1518-1548	254	–34	3.3	4.7	1.8	0		2	700	0.59	0.075	3
M2-29	4-11-77	1515-1545	268	–48	4.0	3.5	3.1	<1		3	680	0.30	0.093	3

Table VI.B-1. (cont'd)

Aerosol Runs			Mean Wind Direction, deg		Wind Velocity, m/sec			Radiation				Wind Stability		
Run No.	Run Date	Time of Run	Relative to True North	Relative to Perpendicular to Spray Line	10m at Effluent Pond	4m at Met. Tower	2m in Spray Field	Cloud Cover in Eighths	Cloud Height, m	Net Radiation Index	Solar Radiation, W/m²	Azimuth St. Dev. σ_A' (rad.)	Elevation St. Dev. σ_E' (rad.)	Pasquill Stability Class
Microbiological Aerosol Runs (cont'd)														
Post-Fair (cont'd)														
M2-30	4-12-77	1615-1645	268	–48	7.8	6.9	5.6	2		2	490	0.16	0.065	4
M2-31	4-13-77	2106-2135	170	+50	4.0	1.5	0.9	<1		–2	28	0.23	0.051	7
M2-32	4-14-77	2010-2040	168	+52	(3.0)	2.2	(1.7)	<1		–2	35	0.23	0.051	6
M2-33	4-19-77	1640-1710	264	–44	5.4	7.2	2.9	<1		2	430	0.17	0.047	4
M2-34	4-19-77	2050-2120	175	+45	4.0	1.9	1.1	<1		–2	<70	0.54	0.051	6
M2-35	4-22-77	1410-1440	215	+5	(5.2)	4.8	4.2	4	6100	2	850	0.29	0.075	3
M2-36	4-23-77	1630-1700	251	–31	(2.7)	4.1	2.2	3	6100	2	450	0.19	0.075	3
M2-37	4-24-77	1335-1405	251	–31	7.2	6.9	6.0	8	4600	2	490	0.16	0.065	4
M2-38	4-24-77	1505-1535	222	–2	5.5	3.4	3.6	8	4500	2	290	0.73	0.075	3
Quality Assurance Aerosol Runs														
Pre-Fair														
M1-16-19	6-7-76	2104-2134	250	–30	2.9	1.6	1.6	7		–1	14	0.38	0.051	6
M1-20-23	6-8-76	1750-1820	255	–35	5.5	2.0	2.0	5		1	390	0.42	0.047	4
M1-24-25	6-9-76	2259-2329	260	–40	1.3	1.1	1.1	<7		–1	14	0.63	0.051	6
M1-26	6-10-76	2212-2242	190	+30	2.8	2.2	2.2	<7		–1	14	0.52	0.051	5
M1-27-30	6-13-76	1707-1737	260	–40	4.9	5.1	5.1	7		1	460	0.31	0.047	4
Post-Fair														
M2-8-9	2-16-77	1805-1835	178	+42	(1.4)	1.7	0.9	5	High	–1	21	0.23	0.051	6
M2-18-21	3-22-77	1821-1851	155	+65	4.4	2.3	2.7	1	5500	–2	21	0.28	0.051	6
M2-27-28	4-5-77	1639-1709	263	–43	(2.1)	3.1	1.8	0		2	480	0.25	0.075	3
Virus Aerosol Runs														
Post-Fair														
V2-I.1	2-25-77	1753-1823	253	–33	(3.2)	5.0	2.6	8	High	–1	35	0.14	0.038	4
V2-I.3	2-26-77	1505-1535	281	–61	(3.1)	2.7	2.5	1	High	1	570	0.33	0.065	4
V2-I.4	2-26-77	1545-1615	274	–54	(3.7)	3.3	3.0	2	High	1	350	0.26	0.052	4
V2-I.5	2-26-77	1624-1654	270	–50	(2.8)	2.5	2.3	3	High	1	290	0.19	0.065	4
V2-I.6	2-26-77	1703-1733	260	–40	(3.3)	3.0	2.7	3	High	1	84	0.19	0.052	4
V2-II.1	4-9-77	1450-1520	266	–46	(6.9)	6.2	5.7	3	1900	3	710	0.23	0.065	4

Table VI.B-1. (cont'd)

Aerosol Runs			Mean Wind Direction, deg		Wind Velocity, m/sec			Radiation				Wind Stability		
Run No.	Run Date	Time of Run	Relative to True North	Relative to Perpendicular to Spray Line	10m at Effluent Pond	4m at Met. Tower	2m in Spray Field	Cloud Cover in Eighths	Cloud Height, m	Net Radiation Index	Solar Radiation, W/m²	Azimuth St. Dev. σ_A' (rad.)	Elevation St. Dev. σ_E' (rad.)	Pasquill Stability Class
Virus Aerosol Runs (cont'd)														
Post-Fair (cont'd)														
V2-II.2	4-9-77	1530-1600	273	-53	(7.3)	6.6	6.1	3	1900	2	670	0.18	0.065	4
V2-II.3	4-9-77	1610-1640	273	-53	(8.0)	7.2	6.6	3	1800	2	520	0.19	0.047	4
V2-II.4	4-9-77	1655-1725	169	+51	(6.9)	6.1	5.6	2	1800	2	360	0.16	0.065	4
V2-II.5	4-9-77	1735-1805	268	-48	(6.1)	5.4	4.9	<1	1700	1	200	0.16	0.047	4
V2-II.6	4-9-77	1815-1845	268	-48	(5.7)	5.0	4.6	<1		1	63	0.16	0.047	4

Fifty-two microbiological aerosol runs were attempted during the Post-Fair sampling period. Three were quality assurance aerosol runs and two were special virus aerosol runs, which involved a total of eleven 30-minute sampling periods. During these quality assurance and virus runs, all samplers were located side-by-side at a distance of 50 meters from the wet-line edge of the spray line. Eighteen microbiological aerosol runs had to be aborted when meteorological conditions violated the aerosol run criteria. Twenty-nine of the Post-Fair aerosol runs met the sampling protocol criteria. Ten dye aerosol runs were also successfully completed during the Post-Fair sampling period. The environmental conditions which existed at the time of the Post-Fair dye and microbiological aerosol runs also appear in Table VI.B-1.

The environmental conditions included in Table VI.B-1 represent measured, calculated, and estimated values. In addition to the time and date, eight descriptive environmental measurements are included. Five of these parameters were measured at several locations in and around the spray field, as indicated by the table headings and as located on the site map, Figure V.A-1. Because the statistical analysis required complete data sets, substitution rules were developed to replace missing values with the best available estimate. The substituted values have been placed in parentheses.

The mean wind direction was obtained from the 10-meter level of the effluent pond station in Pre-Fair and from the 4-meter level of the meteorological tower in Post-Fair. The direction in degrees is given with respect to true north, as well as relative to a line perpendicular to the spray line used for sampling. Wind velocity in meters per second is presented in Table VI.B-1 for three locations: (1) at the 10-meter level near the effluent pond station, (2) at the 4-meter level at the meteorological tower, and (3) at the height of 3-meter in the spray field. Both the wind direction and the velocity shown in Table VI.B-1 represent average values as determined from strip charts that were recorded over the period of each microbiological aerosol run. Those values of wind velocity measured in the field are considered the most accurate reflection of wind conditions affecting the aerosolization of the sprayed wastewater. The wind velocity measured at the 10-meter effluent pond tower is the least representative. Whenever a wind velocity was not available, it was calculated from the most representative value which was available by the relationship:

$$u_2 = u_1 \left(\frac{h_2}{h_1} \right)^p$$

where u_2 and u_1 are the respective wind velocities at heights h_2 and h_1, and p is the wind profile exponent as determined by H. E. Cramer Co. for each of the Pre- and Post-Fair runs. No adjustment for measuring location differences was attempted other than the height adjustment.

Four parameters relating to solar radiation are included in Table VI.B-1. Solar radiation was measured by a short-wave instrument on each Post-Fair run. The following regression equation, which has a coefficient of multiple determination, $r^2 = 0.877$, was developed from the Post-Fair run data and was used to predict solar radiation for the Pre-Fair runs.

$$R = 16.7 + 1095 \sin(SA) - 711 \left(\frac{\sin(SA) \times cc}{h} \right)$$

where R = solar radiation, W/m^2
SA = solar altitude, deg.
cc = fractional cloud cover
h = cloud height factor, when cc is not equal to zero, where
h = 1 for low clouds
h = 2 for middle clouds
h = 3 for high clouds
h = 10 for haze

Solar altitudes were calculated for each run at the Pleasanton location from the date of the run and the time of day halfway through the run. Cloud cover factors were estimated for each run by the field sampling crew.

The standard deviations of the azimuth wind direction (σ_A) and of the elevation wind angle (°E) were determined from the wind direction range, wind speed, and net radiation index, as described by H. E. Cramer Co. ((24) (25)). The H. E. Cramer meteorologists also estimated the Pasquill stability class for each run from these data. The FP rotorod data was used to confirm the field measurements of wind direction mean and standard deviation (σ_A) for the Post-Fair runs.

The air temperature for each Pre- and Post-Fair run is given for four locations in Table VI.B-1. Although differences exist between the sets of air temperature values, those values measured at one location tend to correlate well with values measured at another location. This fact was useful in developing regression equations which allowed the calculation of missing temperature measurements. Missing values of air temperatures upwind (TU) and downwind (TD) of the spray line were calculated from air temperatures measured at the effluent pond (TP) using the following regression equations:

$$TU = 0.82\,TP + 4.0 \qquad (r^2 = 0.523)$$
$$TD = 0.73\,TP + 4.2 \qquad (r^2 = 0.885)$$

Effluent pond air temperatures were directly substituted for missing values of air temperature at the meteorological tower (TM).

Table VI.B-1 also contains relative humidity values for four locations in the vicinity of the spray fields. In addition, relative humidity values were obtained from the Lawrence Laboratory at Livermore which coincide with the day and time of each run. As was the case of air temperature, relative humidity measured at different locations within a general local area tend to differ in a predictable pattern and therefore can be correlated. In order to predict missing values of relative humidity at the effluent pond (RHP) and downwind of the spray line (RHD), regression equations were developed which related those parameters with values of relative humidity which were measured at the meteorological tower (RHM) and upwind of the spray line (RHU), respectively. The following are the regression equations which were used to predict missing values:

$$RHP = 0.427\,RHM + 61 \qquad (r^2 = 0.865)$$
$$RHD = 0.887\,RHU + 11 \qquad (r^2 = 0.925)$$

Values of relative humidity measured at the meteorological tower (RHM) and those values reported by the Lawrence Laboratory at Livermore (RHL) were generally in agreement. Therefore, when one value was missing, the corresponding value at the other location was substituted. It was also determined that relative humidity measured just upwind of the spray line averaged 15 percentage points higher than values reported for the Livermore location; therefore, missing values for the upwind location were approximated by adding 15 percentage points to the corresponding Livermore value: $RHU = RHL + 15$.

Another measurement included in Table VI.B-1 is wastewater temperature, which was recorded at the spray line. Temperatures were observed to vary seasonally and by time of day. In order to calculate missing values, a two-step procedure was used: (1) measured values of wastewater temperature were normalized to the hottest part of the day (1-4 P.M.) and (2) a graph was drawn of the normalized temperature as a function of the date on which it was measured. It was possible to construct a graph that spanned the annual range since Pre-Fair runs were conducted in late spring and Post-Fair runs were conducted in the winter and early spring. Missing values of wastewater temperature were then read from the graph for the corresponding date of the run, and the value was corrected for the actual time of day during which the run was conducted.

b. *Spray Line and Sampler Configurations*

The location and general configuration of the Pre- and Post-Fair microbiological, dye, and quality assurance sampling runs and the Post-Fair virus trial runs are given in Tables VI.B-2 through VI.B-5. The spray fields and staked locations of the distant samplers are shown in Figure V.A-1. The line of spray heads that was rotated daily from one setting to the next through the lettered spray field (A, B, C and D) in a 28-day cycle was used for most of the aerosol sampling. Another line of spray heads was rotated daily through the numbered fields (0, 1, 2, 3 and 4). The side of the sprayer line on which the samplers were located during a run was designated as wet (SW of the sprayer line; still wet from the preceding days' irrigation) or dry (NE of the sprayer line).

For the first four weeks of the seven-week Pre-Fair sampling period, only seven high-volume aerosol samplers were available for use in the microbiological aerosol sampling. One or more of these samplers were often inoperative because of equipment failure or microbiological contamination. The sampling protocol called for eight high-volume samplers on each run; therefore, when it was necessary, the second sampler of the side-by-side sampler pairs was excluded. This is because the five quality assurance runs would provide better measurement variation estimates than could be obtained from the paired sampler data.

The sampler configurations for the Pre-Fair aerosol runs are shown in Table VI.B-3. The standard Pre-Fair distance configuration of the sampler line was used on Runs 1 and 3. A paired sampler configuration was employed on Runs 4 and 5, to assess the basic dye level variability at a given downwind distance due both to inherent variability in the sampled aerosol and to sampler variation. A modification of the standard configuration was used on Runs 6 and 10 when it became apparent that sampling within 10 meters of the wet-line edge yielded low dye concentrations. Configuration A was utilized for Run 9. While sprayer lines were also operating in field 2 on Runs 3 to 6, this had no effect on the dye experiment; the dye was only injected into the sprayer line directly upwind from the samplers. As shown in Table VI.B-3, the standard Post-Fair dye sampler configuration was used for all of the Post-Fair dye aerosol runs.

For the Pre- and Post-Fair quality assurance aerosol runs and for the Post-Fair virus trial runs, the samplers in each run were set side-by-side about 3 meters apart (1 meter apart in Pre-Fair) at a certain distance from the wet-line edge. In the Pre-Fair quality assurance runs, the sampler lines were set at different distances from the wet-line edge with the distances recorded in Table VI.B-4. For the Post-Fair quality assurance aerosol runs and the virus trial runs, the sampler lines were set at 50 meters from the wet-line edge as shown in Tables VI.B-4 and VI.B-5.

Concentration patterns and sampler locations for the Pre-Fair runs appear in Appendix B of the H. E. Cramer Report #TR-76-303-03 ((26)). Concentration patterns and sampler configurations for the Post-Fair runs appear in Appendices F and G of the H. E. Cramer Report #TR-77-309-01 ((27)).

For the Pre-Fair dye and microbiological aerosol runs, source strength profiles are included in Appendix C of the H. E. Cramer Report #TR-76-303-03 ((28)). The individual spray head flow rates are tabulated in Appendices B and C of the H. E. Cramer Report #TR-77-309-01 ((29)) for the Post-Fair dye, microbiological and virus runs.

2. Sampled Concentration Data

a. *Dye Runs*

The wastewater and aerosol sample dye concentrations obtained on the Pre- and Post-Fair dye runs are presented in Tables VI.B-6 and VI.B-7, respectively. These tables also contain the prependicular distance of each AGI sampler from the wet-line edge. For the source dye concentration, wastewater samples were taken before and after a run, and the two values obtained were averaged to calculate the source dye concentration mean.

Table VI.B-2.
SAMPLING CONDITIONS FOR MICROBIOLOGICAL AEROSOL RUNS*

Pre-Fair

Aerosol Run No.	Sprayer Line Source Sampled		Location of Sampler Line		Sampler Line Configuration	Other Fields Operating
	Field	Setting	Side of Sprayer Line	Position (facing sprayer line)		Field Setting
M1-1	B	1	Dry	Left	Standard	2-5
M1-2	B	2	Dry	Left	Standard	2-6
M1-3	B	2	Dry	Left	Standard	2-6
M1-4	C	3	Dry	Left	Standard	E-2
M1-5	C	3	Dry	Left	Standard	E-2
M1-6	C	7	Dry	Right	Standard	0-6, F-1
M1-7	C	7	Dry	Right	Standard	0-6, F-1
M1-8	D	4	Dry	Left	Standard	F-1
M1-9	3	1	Dry	Center	Standard	G-1
M1-10	3	1	Dry	Center	Mod Std	D-7, G-1
M1-11	3	2	Dry	Right	Mod Std	A-1, G-2
M1-12	3	4	Dry	Right	Mod Std	A-3, G-4
M1-13	3	4	Dry	Center	Standard	A-3
M1-14	3	4	Dry	Center	Standard	A-3, G-4
M1-15	B	3	Dry	Right	Mod Std	1-1, H-3
M1-31	C	7	Dry	Center	A	D-6, 1-6
M1-32	D	1	Dry	Left	A	D-7, I-7
M1-33	D	1	Dry	Left	B	0-7, I-7
M1-34	D	2	Dry	Right	B	I-7
M1-35	D	3	Wet	Center	A	4-2, E-2

*See pages 26-28.

Post-Fair

Run No.	Sprayer Line Source Sampled		Location of Sampler Line		Distant Sampler Lines	Near Rotored Lines	Other Fields Operating	Other Spray Fields Contributing to Aerosol Sampled Downwind
	Field	Setting	Side of Sprayer Line	Position (facing sprayer line)				
M2-1	C	4	Wet	Left	E	L.E	1,I	
M2-2	D	1	Wet	Left	E	F	4,I	
M2-3	D	1	Wet	Center	E	F	4,I	
M2-4	D	6	Wet	Center	F	F	4,E,F	
M2-5	D	6	Wet	Left	E	F	4,E,F	
M2-6	B	2	Dry	Right	D	A	2,G	
M2-10	D	2	Dry	Left	C,I,K	H,B	4,I	4
M2-11	D	3	Wet	Right	G,E	F,G	4	
M2-12	D	3	Wet	Right	G,E	F,G		
M2-13	D	7	Dry	Left	G,I,K	H,B	3,E,F	
M2-14	B	7	Dry	Center	B	A	1,H	
M2-15	C	2	Dry	Left	K,H	M,A	1,H,WLF*	
M2-16	C	3	Wet	Center	E	L	1,H,WLF	
M2-17	C	4	Dry	Left	K,H	M	1,I,WLF	I
M2-22	D	4	Wet	Right	G,E	F,L	4,E,F,WLF	E,F
M2-23	D	5	Wet	Right	G,E	F,L	4,E,F,WLF	
M2-24	D	5	Dry	Left	K,I	H,B	4,E,F,WLF	
M2-25	D	6	Dry	Left	I,G,C	B,H	4,E,F,WLF	
M2-26	D	6	Dry	Left	I,G,C	B,H	4,E,F,WLF	E,F
M2-29	B	7	Dry	Left	H,B,K	M,A	1,H	
M2-30	C	1	Dry	Left	K,H,G	M,A	1,H	
M2-31	C	2	Dry	Right	D	A	1,H	
M2-32	C	3	Dry	Right	D	A	1,H	
M2-33	D	1	Dry	Left	K,I,G,C	H,G	4,I	I
M2-34	D	1	Dry	Right	D	B	4,I	
M2-35	D	4	Dry	Center	C,D	B	4,E,F	E,F
M2-36	D	5	Dry	Left	K,I,G	H,G	4,E,F	E,F
M2-37	D	6	Dry	Left	I,C	H,G	4,E,F	
M2-38	D	6	Dry	Left	I,C	H,G	4,E,F	4

*West Lake Field

Aerosol dye concentrations versus downwind distance are plotted in Figure VI.B-1 for each of the seven Pre-Fair dye runs. The mean downwind distance from the wet-line edge used as the abscissa in these plots was obtained by dividing the perpendicular distance in Table VI.B-6 by the sine of the mean wind angle θ.

Some interesting observations can be made by scanning Figure VI.B-1. The relationship of aerosol dye concentration to downwind distance appears to differ substantially over the seven runs. On each of dye Runs D1-6 and D1-9, there is an obvious decrease of dye concentration with increasing distance from the wetline edge. It might be noted that these were the two dye runs located in the center sampler position. The other dye runs (D1-1, D1-3, D1-4, D1-5 and D1-10) do not exhibit a consistent trend in the dye concentration with increasing downwind sampler distance.

Table VI.B-3.
SAMPLING CONDITIONS FOR DYE AEROSOL RUNS

Pre-Fair

Dye Run No.	Sprayer Line Source Sampled		Location of Sampler Line		Sampler Line Configuration
	Field	Setting	Side of Sprayer Line	Position (facing sprayer line)	
D1-1	B	1	Dry	Left	Standard
D1-3	2	1	Dry	Left	Standard
D1-4	2	4	Dry	Left	Paired
D1-5	2	4	Dry	Left	Paired
D1-6	2	5	Dry	Center	Mod Std
D1-9	C	7	Wet	Center	A
D1-10	D	2	Dry	Left	Mod Std

Post-Fair

Run No.	Sprayer Line Source Sampled		Location of Sampler Line		Sampler Line Configuration
	Field	Setting	Side of Sprayer Line	Position (facing sprayer line)	
D2-1	D	3	Wet	Center	Dye (50, 75, 100)
D2-2	D	6	Wet	Center	Dye (50, 75, 100)
D2-4	D	7	Wet	Center	Dye (50, 75, 100)
D2-5	D	7	Wet	Center	Dye (50, 75, 100)
D2-6	B	2	Wet	Center	Dye (50, 75, 100)
D2-7	B	3	Wet	Center	Dye (50, 75, 100)
D2-8	B	3	Wet	Center	Dye (50, 75, 100)
D2-9	B	3	Wet	Center	Dye (50, 75, 100)
D2-10	B	3	Wet	Center	Dye (50, 75, 100)
D2-11	B	3	Wet	Center	Dye (50, 75, 100)

The plots for Runs 1, 3, 4 and 9 disclose one or more apparently erratic sampler points within 50 meters downwind of the wet-line edge for which the sampled dye concentration differs appreciably from the distance pattern suggested by the other sampler points. It appears that dye samplers should not be located closer than 50 meters from the dye aerosol source.

b. *Microbiological Runs*

All of the adjusted and footnoted microbiological concentration data obtained on the 20 Pre-Fair aerosol runs and the 29 Post-Fair aerosol runs are presented in the tables of Appendix F. Each Appendix F table contains all of the analysis results (from every high-volume sample on all the runs for either Pre-Fair or Post-Fair) for a single type of analysis. The tables are formatted according to the downwind sampler distances from the wet-line edge that were used in the aerosol run sampler configuration. A list of footnotes, special data symbols, and microbiological units precedes the tables in Appendix F. When sample contamination affecting the microorganism concentration result was inferred, the analysis result has been underlined. The quality of the footnoted data must be evaluated taking the footnote(s) into account. Special data symbols accompany or replace the usual data value in the indicated circumstances. The units identify the type of assay procedure used to obtain the quantitative results.

A 30-minute composite wastewater sample was taken from a spray head in the sprayer line during each aerosol run. This sample was analyzed for four microorganism groups in Pre-Fair and for all five of the Post-Fair microorganisms. These results are shown in Appendix F, in the third column of the Pre-Fair

Table VI.B-4.
SAMPLING CONDITIONS FOR QUALITY ASSURANCE AEROSOL RUNS

Run No.	Sprayer Line Source Sampled		Location of Sampler Line		Distance from Wet Line Edge, m
	Field	Setting	Side of Sprayer Line	Position (facing sprayer line)	
PRE-FAIR					
M1-16-19	C	1	Dry	Center	25
M1-20-23	C	2	Dry	Center	30
M1-24-25	C	3	Dry	Center	25
M1-26	C	4	Dry	Center	20
M1-27-30	C	7	Dry	Left	40
POST-FAIR					
M2-8-9	C	2	Dry	Center	50
M2-18-21	D	1	Dry	Right	50
M2-27-28	B	1	Dry	Center	50

Table VI.B-5.
SAMPLING CONDITIONS FOR VIRUS AEROSOL RUNS
POST-FAIR

Run No.	Sprayer Line Source Sampled		Location of Sampler Line		Distance from Wet Line Edge, m
	Field	Setting	Side of Sprayer Line	Position (facing sprayer line)	
V2-I.3-6	D	5	Dry	Left	50
V2-II.1-6	B	5	Dry	Left	50

Table VI.B-6.
PRE-FAIR DYE AEROSOL RUN CONCENTRATION DATA

Dye Run No.	Wastewater Data	Aerosol Sampler Data	
	Source Dye Concentration (μg/l)	Perpendicular Distance from Wet Line Edge (m)	Aerosol Dye Concentration (μg/m^3)
D1-1	Mean: 91,700	5	1.77
	Before: 93,000	10	4.06
	After: 90,333	15	3.18
		20	15.89
		50	3.18
		100	1.94
D1-3	Mean: 85,000	5	1.29
	Before: 86,000	10	1.82
	After: 84,000	15	2.61
		20	1.71
		20	1.94
		50	1.65
		100	1.77
		100	1.71
D1-4	Mean: 96,500	10	2.88
		10	2.35
	Before: 97,000	20	2.47
	After: 96,000	20	2.00
		30	1.35
		30	0.88
		40	2.77
		40	2.82
D1-5	Mean: 72,000	15	2.94
		15	3.06
	Before: 76,000	25	3.35
	After: 68,000	25	3.06
		35	3.71
		35	3.77
		45	3.24

Table VI.B-6. (cont'd)

Dye Run No.	Wastewater Data	Aerosol Sampler Data	
	Source Dye Concentration (µg/l)	Perpendicular Distance from Wet Line Edge (m)	Aerosol Dye Concentration (µg/m^3)
D1-6	Mean: 96,000	10	9.89
	Before: 100,000	15	9.77
	After: 92,000		
		20	7.47
		20	9.12
		30	8.06
		50	4.35
		100	2.77
		100	5.28
D1-9	Mean: 17,100	10	2.29
		10	1.82
	Before: 18,000		
	After: 16,200	20	1.00
		30	1.71
		40	1.12
		40	1.06
		50	0.82
		50	1.00
D1-10	Mean: 18,800	10	0.13
	Before: 20,600	20	0.12
	After 17,000	20	0.13
		30	0.18
		40	0.18
		50	0.23
		100	0.18
		100	0.18

Table VI.B-7.
POST-FAIR DYE AEROSOL RUN CONCENTRATION DATA

Dye Run No.	Wastewater Data	Aerosol Sampler Data	
	Source Dye Concentration (µg/l)	Perpendicular Distance from Wet Line Edge (m)	Aerosol Dye Concentration (µg/m³)
D2-1	Mean: 21,000 Before: 20,500 After: 21,500	50	0.53
		50	0.59
		50	0.53
		50	0.47
		75	0.29
		75	0.26
		100	0.14
		100	0.12
D2-2	Mean: 21,300 Before: 21,900 After: 20,600	50	0.67
		50	0.69
		50	0.62
		50	0.58
		75	0.41
		75	0.47
		100	0.34
		100	0.39
D2-4	Mean: 27,400 Before: 27,200 After: 27,600	50	0.56
		50	0.54
		50	0.46
		50	0.48
		75	0.29
		75	0.29
		100	0.19
		100	0.20
D2-5	Mean: 26,100 Before: 26,800 After: 25,400	50	0.62
		50	0.52
		50	0.54
		50	0.42
		75	0.29
		75	0.25
		100	0.18
		100	0.16

Table VI.B-7. (cont'd)

Dye Run No.	Wastewater Data		Aerosol Sampler Data	
	Source Dye Concentration (μg/l)		Perpendicular Distance from Wet Line Edge (m)	Aerosol Dye Concentration (μg/m^3)
D2-6	Mean:	22,100	50	0.49
			50	0.65
	Before:	21,200		
	After:	23,000	50	0.38
			50	0.45
			75	0.16
			75	0.12
			100	0.07
			100	0.15
D2-7	Mean:	25,600	50	0.62
			50	0.35
	Before:	18,600		
	After:	32,500	50	0.29
			50	0.48
			75	0.26
			75	0.28
			100	0.19
			100	0.16
D2-8	Mean:	31,000	50	0.65
			50	0.34
	Before:	29,500		
	After:	32,500	50	0.51
			50	0.53
			75	0.39
			75	0.24
			100	0.26
			100	0.13
D2-9	Mean:	25,500	50	0.33
			50	0.32
	Before:	23,900		
	After:	27,000	50	0.36
			50	0.47
			75	0.17
			75	0.19
			100	0.12
			100	0.12

Table VI.B-7. (cont'd)

Dye Run No.	Wastewater Data	Aerosol Sampler Data	
	Source Dye Concentration (μg/l)	Perpendicular Distance from Wet Line Edge (m)	Aerosol Dye Concentration (μg/m³)
D2-10	Mean: 28,700	50	0.12
		50	0.14
	Before: 28,800		
	After: 28,500	50	0.22
		50	0.15
		75	0.18
		75	0.13
		100	0.09
		100	0.08
D2-11	Mean: 27,400	50	0.19
		50	0.17
	Before: 27,500		
	After: 27,300	50	0.18
		50	0.25
		75	0.14
		75	0.15
		100	0.20
		100	0.17

Figure VI.B-1.
PLOTS OF AEROSOL DYE CONCENTRATION WITH DOWNWIND DISTANCE

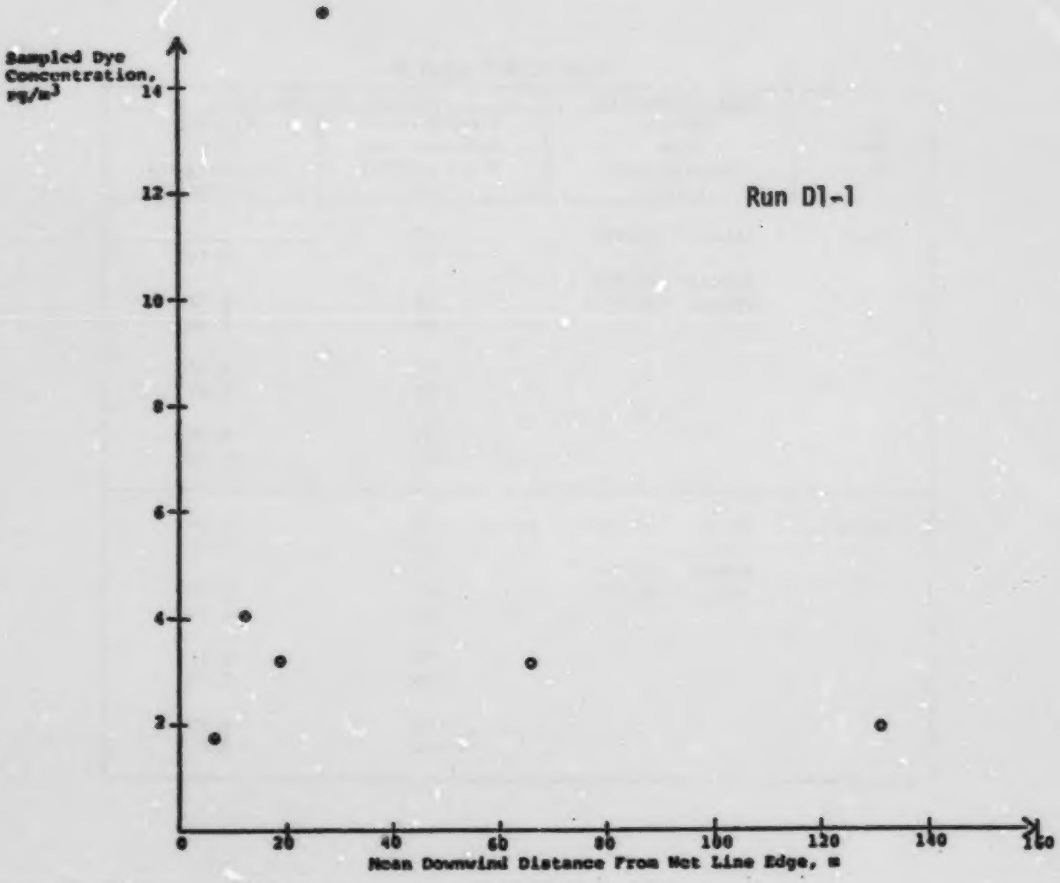
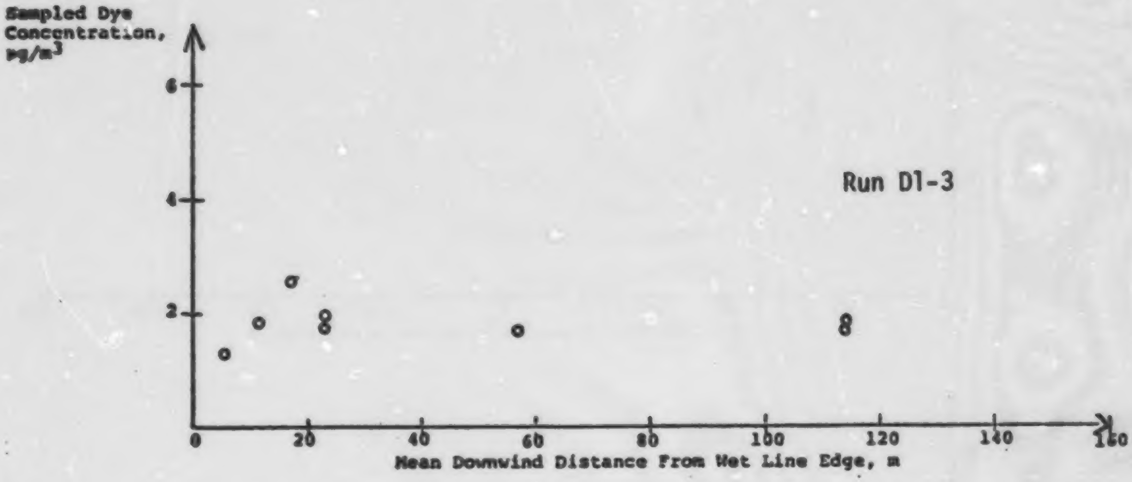


Figure VI.B-1. (continued)



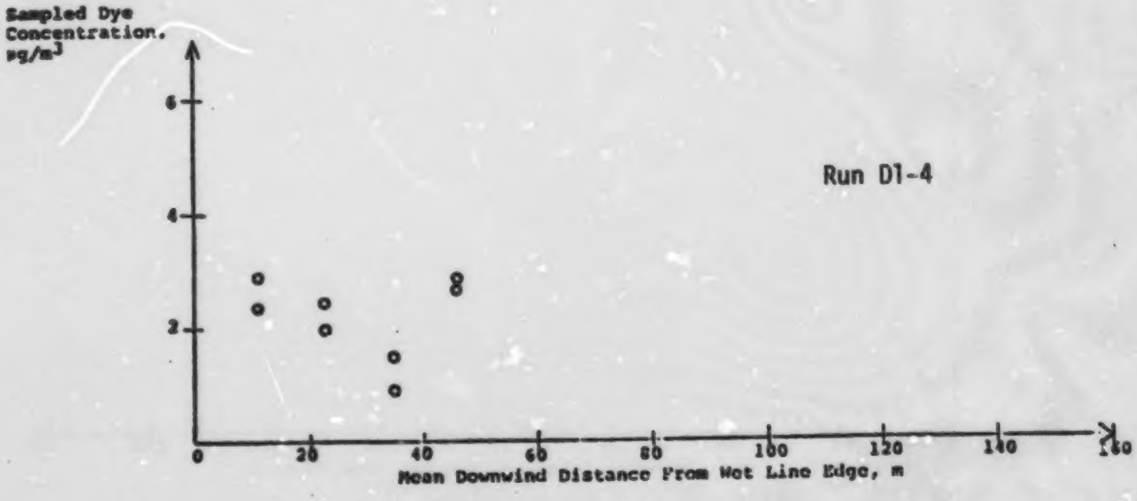


Figure VI.B-1. (continued)

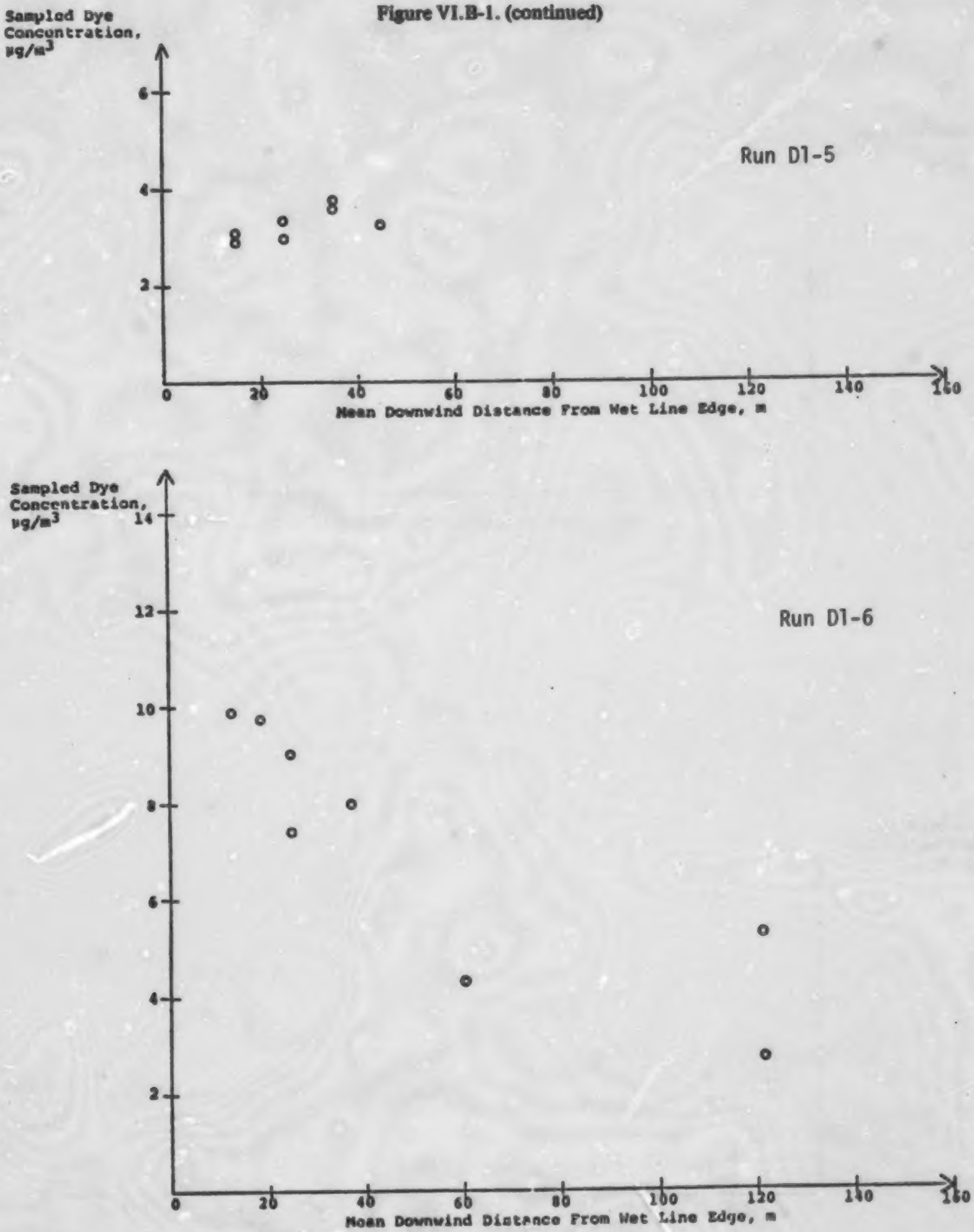
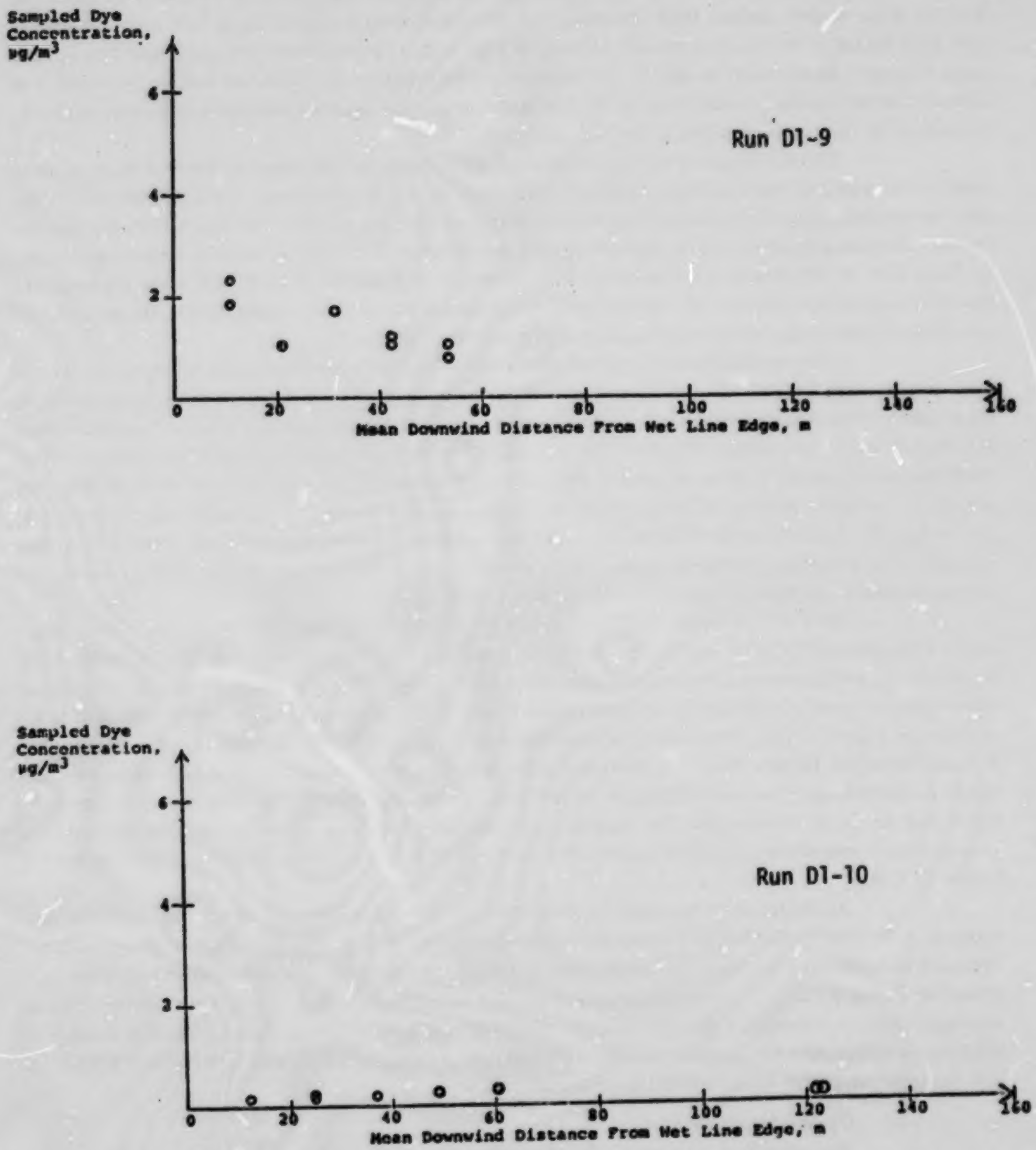


Figure VI.B-1. (continued)



tables for total coliform, fecal coliform, standard bacterial plate count, and coliphage, and on all of the Post-Fair tables.

The upwind sampler was placed at an appropriate upwind sampler location based on wind direction before the run. For Pre-Fair, there were three preselected locations in elevated wooded areas; the distance of the upwind sampler from the configured downwind samplers ranged from 1400 meters to greater than 3200 meters, with a median upwind distance of 1800 meters. During Post-Fair, there were five upwind sampler stations whose elevation, terrain and land usage were similar to the downwind sampler positions. The upwind sampler was also located closer to the configured downwind samplers and occasionally was located to one side of the samplers depending on the wind direction.

Within 100 meters of the wet-line edge, the aerosol concentrations of standard bacterial plate count, total coliform, fecal coliform, coliphage, fecal streptococci, *Pseudomonas*, and *Clostridium perfringens* were generally quantifiable above the minimum detection limit. Because the Post-Fair wastewater concentrations of mycobacteria were lower than anticipated, mycobacteria were seldom found in the aerosol samples on Runs M2-1 to M2-26 above the detection limit. However, in Runs M2-29 to M2-37, when the detection limit was lowered by a factor of 30, mycobacteria were found in almost every sample. Hence, the aerosol concentrations of these eight microorganism groups warrant statistical analysis.

Fourteen biochemical confirmation tests for *Klebsiella* were conducted on every mucoid colony from the aerosol samples on the 20 Pre-Fair microbiological aerosol runs. Through this exhaustive effort, *Klebsiella* was found in only four of the aerosol samples: *Klebsiella ozaenae* on Run M1-8 at 5 meters or Run M1-10 at 50 meters and on Run M1-14 at 50 meters; and *Klebsiella pneumoniae* on Run 12 at 20 meters. After confirmation testing for viruses, no positive three-day virus plaque counts were obtained from the Pre-Fair aerosol run samples. Only two of these aerosol samples had positive five-day virus plaques: the 10 meter sampler on Run M1-9 and the upwind sampler on Run M1-13. The discovery of *Klebsiella* and viruses in the aerosol is certainly important. However, the *Klebsiella*, three-day virus, and five-day virus aerosol concentrations are not suitable microorganism groups for the statistical analyses.

An examination of the Pre-Fair and Post-Fair aerosol concentration values with distance across a microbiological aerosol run in the quantitative aerosol data tables reveals a definite downwind distance pattern: a reduction in concentration with increasing downwind sampler distance. The microbiological concentration reduction with distance is more pronounced than the dye concentration reduction with distance exhibited in Figure VI.B-1. There clearly are microbiological decay factors in addition to the aerosol formation and dispersion factors. Also, it appears that microorganism die-off accumulates with distance from the source or aerosol age. The microbiological aerosol levels on the nighttime and evening runs were generally higher than on the afternoon runs. This suggests confirmation of the Phase I finding that solar radiation is a very significant microbiological decay factor. This topic will be given a more rigorous statistical treatment in Section VI.C.5.

As discussed in Appendix D, smoothing of the microbiological aerosol run data was necessary to make it amenable for developing the microbiological dispersion model. The smoothing procedures described in Appendix D (designating background and downwind samplers, computing the background concentration B, computing the downwind concentration C_d at sampler distance d, and excluding unusable runs) were applied to the Appendix F data for the eight microorganism groups that warrant statistical analysis. The resulting smoothed data for the microbiological aerosol runs are presented in Tables VI.B-8 through VI.B-15, with each microorganism group appearing on a separate table.

c. *Quality Assurance Runs*

The purpose of the aerosol quality assurance runs in Pre-Fair and Post-Fair was to determine whether there were systematic differences or biases among the high-volume aerosol samplers used in the aero-

Table VI.B-8.
SMOOTHED STANDARD BACTERIAL PLATE COUNTS BY SAMPLER DISTANCE FROM MICROBIOLOGICAL AEROSOL RUNS

Aerosol Run Number	Run Date	Wastewater Concentration (No./100ml)	Aerosol Concentrations (No./m³ of air)									Distant Sampler Distance
			Background B	Downwind Concentrations C_d at Sampler Distance d								
				5m	10m	25m	30m	40m	50m	100m	Distant	
M1-1	5-4-76	110 x 10^4	140	9800	1400	830						
M1-2	5-6-76	120 x 10^4	2000	6700	6000	8600			5500	6500		
M1-3	5-6-76	110 x 10^4	600		4900	5800			1500	1300		
M1-5	5-13-76	167 x 10^4	1200	2600	2100	2000						
M1-6	5-17-76	78 x 10^4	300	1700	1600	3000						
M1-7	5-17-76	46 x 10^4	600	2000	2000	1700						
M1-8	5-21-76	75 x 10^4	100		1000	3200			340 360			
M1-9	5-24-76	104 x 10^4	1430	6300	3000				1800			
M1-10	5-24-76	145 x 10^4	1600		4500		2200		2000			
M1-11	5-25-76	38 x 10^4	840		3000		2000		2200	1400		
M1-12	5-27-76	34 x 10^4	150		850	2100			750	980		
M1-13	5-27-76	25 x 10^4	64			2800			790	1400	980	(200m)
M1-15	6-3-76	46 x 10^4	2100			2500						
M1-31	6-14-76	16 x 10^4	220		3500	3000	3800		2000 2700			
M1-32	6-15-76	20 x 10^4	570		1500	1200	3800	6300				
M1-33	6-15-76	95 x 10^4	680			5600 5000	5100	3300				
M1-34	6-16-76	54 x 10^4	1800			1650						
M1-35	6-17-76	76 x 10^4	380		5200 1000	2900	1600	1900	1300 1300			
M2-1	1-21-77	15 x 10^4	310						830	830	430	(220m)
M2-3	1-25-77	113 x 10^4	1500						1770	4500 3800		
M2-4	1-26-77	27 x 10^4	650						1260			
M2-6	2-9-77	7.0x 10^4	85						480 290	92 500		
M2-12	2-24-77	2.1x 10^4	90						95	900		
M2-15	3-16-77	73 x 10^4	180						1400 330	380		
M2-16	3-17-77	106 x 10^4	38						1100 1300	190 83	130	(290m)
M2-17	3-18-77	76 x 10^4	130						950 720	2400	360	(340m)
M2-22	3-25-77	2.2x 10^4	47						60 72	56		
M2-23	3-26-77	20 x 10^4	38						66	97 110		
M2-24	3-26-77	41 x 10^4	48						190 190	60		
M2-25	3-27-77	25 x 10^4	63						310 270	98 150		
M2-29	4-11-77	44 x 10^4	370						1300 1900	1700 3200		
M2-31	4-13-77	67 x 10^4	360						1080	900 530		
M2-32	4-14-77	75 x 10^4	300						520	520		
M2-34	4-19-77	16 x 10^4	930						4800 2300	1900		
M2-35	4-22-77	6.9x 10^4	140						170	900 430		
M2-38	4-24-77	15 x 10^4	210						2100	870 1230	300	(430m)

Table VI.B-9.
SMOOTHED TOTAL COLIFORM CONCENTRATIONS BY SAMPLER DISTANCE FROM MICROBIOLOGICAL AEROSOL RUNS

Aerosol Run Number	Run Date	Wastewater Concentration (MFC/100ml)	Aerosol Concentrations (MFC/m³ of air)									Distant Sampler Distance
			Background B	Downwind Concentrations C_d at Sampler Distance d								
				5m	10m	20m	30m	40m	50m	100m	Distant	
M1-2	5-6-76	2070 x 10^3	0.15	9.2	10.5	17.2 20.0			8.3	5.1		
M1-3	5-6-76	2140 x 10^3	0.15	12.7	8.1	10.9 12.6			3.0	0.5		
M1-4	5-13-76	680 x 10^3	0.07	1.7	2.1	0.2						
M1-5	5-13-76	720 x 10^3	0.07	5.8	1.4	0.2				0.6		
M1-6	5-17-76	930 x 10^3	0.1	6.5	4.6	7.7				0.5		
M1-7	5-17-76	700 x 10^3	0.1	4.3	1.2	5.2			0.45			
M1-8	5-21-76	960 x 10^3	0.1	10.8	15.5	1.1			5.2	4.4		
M1-9	5-24-76	1040 x 10^3	0.15	18.0	38				32	4.9		
M1-10	5-24-76	1280 x 10^3	0.5		57	93	46		8.3	0.15		
M1-11	5-25-76	1100 x 10^3	0.1		43	46	53		1.4	0.15		
M1-12	5-27-76	470 x 10^3	0.1		2.0	6.5			6.2	4.3	2.6	(200m)
M1-13	5-27-76	690 x 10^3	0.15			11.7			14.5	4.1	2.2	(200m)
M1-14	5-27-76	750 x 10^3	0.1			47			2.1	0.9 2.0		
M1-15	6-3-76	980 x 10^3	0.1		3.2	2.2			0.4 1.5			
M1-31	6-14-76	970 x 10^3	0.05		13.2	4.7	2.6					
M1-32	6-15-76	265 x 10^3	0.03		0.53 0.67		0.45					
M1-33	6-16-76	170 x 10^3	0.08			0.75		1.3				
M1-34	6-16-76	550 x 10^3	0.08			1.7 2.3 3.8	0.8					
M1-35	6-17-76	350 x 10^3	0.1		19.3 30.5	12.0	6.6	5.1	2.0 2.6			
M2-1	1-21-77	60 x 10^3	0.025						6.7 7.5	0.4		
M2-2	1-25-77	280 x 10^3	0.02						2.0 1.5	0.4 1.6		
M2-3	1-25-77	450 x 10^3	0.025						37 31	15.2 10.5	0.3	(300m)
M2-4	1-30-77	260 x 10^3	0.01						6.5 5.8	2.0 1.3		
M2-5	1-30-77	340 x 10^3	0.02						4.8 5.5	2.6 3.1		
M2-6	2-9-77	220 x 10^3	0.05						2.1 1.9	0.2 0.2		
M2-10	2-23-77	410 x 10^3	0.1						1.3 5.5	4.7 5.3		
M2-11	2-24-77	340 x 10^3	0.02						3.1 2.2	0.9 1.3		
M2-12	2-24-77	360 x 10^3	0.02						0.3 2.9	1.3 0.2		
M2-13	2-28-77	390 x 10^3	0.05						1.7 2.7	2.8 3.3		
M2-14	3-14-77	420 x 10^3	0.01						13.0 10.8	1.1 1.3		
M2-15	3-16-77	690 x 10^3	0.01						5.3 4.5	1.6 1.1		
M2-16	3-17-77	1100 x 10^3	0.02						9.7 12.2	4.3 1.8	0.2	(220m)
M2-17	3-18-77	1200 x 10^3	0.1						5.7 7.7	5.7 2.4	0.2	(340m)
M2-22	3-25-77	860 x 10^3	0.02						2.0 2.0	0.4 0.2		
M2-24	3-26-77	740 x 10^3	0.05						1.8 0.6	0.1		
M2-25	3-27-77	730 x 10^3	0.01						2.2 3.8	0.36		
M2-26	3-27-77	670 x 10^3	0.017						0.3 0.4	0.025		
M2-29	4-11-77	1600 x 10^3	0.01						0.1			
M2-30	4-12-77	640 x 10^3	0.01						1.2 0.7	2.0 0.6	0.2 0.2	0.2(435/505/580m)
M2-31	4-13-77	450 x 10^3	0.05						7.8 7.5	4.8		
M2-32	4-14-77	1200 x 10^3	0.01						2.0 2.3	1.5 1.5		
M2-33	4-19-77	390 x 10^3	0.02						14.0 13.5	0.2		
M2-34	4-19-77	540 x 10^3	0.45						6.7			
M2-35	4-22-77	360 x 10^3	0.025						2.0	2.0 1.7	0.1	(650m)
M2-36	4-23-77	410 x 10^3	0.02						1.3	0.1		
M2-37	4-24-77	450 x 10^3	0.01						1.7 2.5	0.25		
M2-38	4-24-77	410 x 10^3	0.01						1.1 0.7	0.025		

Table. VI.B-10.
SMOOTHED FECAL COLIFORM CONCENTRATIONS BY SAMPLER DISTANCE FROM MICROBIOLOGICAL AEROSOL RUNS

Aerosol Run Number	Run Date	Wastewater Concentration (MFC/100ml)	Aerosol Concentrations (MFC/m³ of air) Background B	Downwind Concentrations C_d at Sampler Distance d 5m	10m	20m	30m	40m	50m	100m
M1-2	5-5-76	186 x 10³	0.02	2.0	2.1	4.4 2.1			1.2	0.2
M1-3	5-5-76	174 x 10³	0.05	0.9	1.7	3.0 1.0			0.075	
M1-5	5-13-76	180 x 10³	0.02	1.1	0.7	0.1				
M1-6	5-17-76	75 x 10³	0.075	1.1	0.3	1.4				
M1-7	5-17-76	110 x 10³	0.075	0.6	0.75					0.25
M1-8	5-21-76	80 x 10³	0.02	0.8						
M1-9	5-24-76	81 x 10³	0.075	3.1	2.3	2.0			1.2	0.2
M1-10	5-24-76	125 x 10³	0.3		9.5	12.2	3.8		5.6	0.5
M1-11	5-25-76	124 x 10³	0.06		6.6	6.2	1.3		0.5	
M1-15	6-3-76	57 x 10³	0.02		1.8	1.9	0.2		0.5	0.1
M1-31	6-14-76	137 x 10³	0.05		2.9	0.6	0.6		0.2 0.2	
M1-32	6-15-76	24 x 10³	0.02		0.15	0.33				
M1-34	6-16-76	81 x 10³	0.075			0.4 1.0 0.6	0.25		0.7	
M1-35	6-17-76	45 x 10³	0.05		4.9 4.4	9.9	1.2	0.6	0.4 0.5	

Table VI.B-11.
SMOOTHED COLIPHAGE CONCENTRATIONS BY SAMPLER DISTANCE FROM MICROBIOLOGICAL AEROSOL RUNS

Aerosol Run Number	Run Date	Wastewater Concentration (PFU/l)	Aerosol Concentrations (PFU/m³ of air)									Distant Sampler Distance
			Background B	Downwind Concentrations C_d at Sampler Distance d								
				5m	10m	20m	30m	40m	50m	100m	Distant	
M1-3	5-5-76	95 x 10^3	0.0		0.15	0.2						
M1-5	5-13-76	170 x 10^3	0.0		0.05					0.1		
M1-6	5-17-76	220 x 10^3	0.0	1.0	0.6	0.8				0.05		
M1-7	5-17-76	230 x 10^3	0.0	0.1		0.3			0.025	0.1		
M1-8	5-21-76	61 x 10^3	0.0	0.7	0.4	0.1 0.3			0.05			
M1-9	5-24-76	96 x 10^3	0.0	1.1	0.1	1.2			0.8	0.3		
M1-10	5-24-76	130 x 10^3	0.0		2.0	3.7 1.1	1.4		2.6	0.2		
M1-11	5-26-76	140 x 10^3	0.0		2.3	0.8 1.4	1.1		0.6	0.4		
M1-12	5-27-76	110 x 10^3	0.0		0.9	0.7 0.3			0.2	0.1		
M1-13	5-27-76	170 x 10^3	0.0			1.1			1.0	0.7	0.2	(200m)
M1-14	5-27-76	210 x 10^3	0.0			3.3			0.8	0.6	0.2	(200m)
M1-15	6-3-76	310 x 10^3	0.0		0.1	0.7	0.3		0.3	0.2 0.1		
M1-31	6-14-76	330 x 10^3	0.0		0.7	0.6	0.7		0.013			
M1-32	6-15-76	320 x 10^3	0.0		0.025 0.2	0.1		0.013				
M1-33	6-15-76	240 x 10^3	0.0			0.1 0.4	0.2	0.025				
M1-35	6-17-76	170 x 10^3	0.0		1.8	0.8	1.1	0.5	0.2 0.6			
M2-1	1-21-77	180 x 10^3	0.0						0.4 0.3	0.5 0.3		
M2-2	1-25-77	94 x 10^3	0.075						0.7 0.4	0.2		
M2-3	1-26-77	160 x 10^3	0.1						0.8 0.4	0.2		
M2-4	1-30-77	120 x 10^3	0.025						0.8 0.7	0.15		
M2-5	1-30-77	170 x 10^3	0.0						0.4 0.1	0.3		
M2-10	2-23-77	300 x 10^3	0.0						0.1 1.1	0.9 1.2		
M2-11	2-24-77	390 x 10^3	0.0						0.4 0.7	0.3 0.1		
M2-12	2-24-77	230 x 10^3	0.0						0.3 1.1	0.4 0.1	0.3	(220m)
M2-13	2-28-77	310 x 10^3	0.0						1.1 1.3	1.2 0.9		
M2-14	3-14-77	190 x 10^3	0.025						2.8 2.1	0.8 0.5		
M2-15	3-16-77	120 x 10^3	0.075						0.3 0.4	0.1 0.3		
M2-16	3-17-77	140 x 10^3	0.0						0.9 0.7	0.55		
M2-17	3-18-77	190 x 10^3	0.0						0.5 0.5	0.1 0.4	0.1	(340m)
M2-22	3-25-77	170 x 10^3	0.0						1.1 0.4	0.05		
M2-23	3-26-77	380 x 10^3	0.025						0.15	0.05		
M2-24	3-26-77	700 x 10^3	0.0						1.6 2.1	0.2 0.7		
M2-25	3-27-77	1200 x 10^3	0.0						2.5 2.2	0.7 0.3		
M2-26	3-27-77	930 x 10^3	0.033						0.15			
M2-29	4-11-77	400 x 10^3	0.0						0.7 0.4	0.05		
M2-30	4-12-77	180 x 10^3	0.0						0.1 0.3	0.15		
M2-31	4-13-77	240 x 10^3	0.0						0.8 0.8	0.8 0.1		
M2-32	4-14-77	240 x 10^3	0.0						0.8 0.4	0.013		
M2-33	4-19-77	450 x 10^3	0.0						0.3 0.025	0.4		
M2-34	4-19-77	200 x 10^3	0.0						0.1 0.2	0.3 0.2		
M2-35	4-22-77	1200 x 10^3	0.0						2.6 2.8	1.1 1.1		
M2-36	4-23-77	780 x 10^3	0.0						0.4 0.1	0.3 0.1		
M2-37	4-24-77	480 x 10^3	0.0						0.4 0.4	0.1 0.4		
M2-38	4-24-77	430 x 10^3	0.0						0.4 0.4	0.3 0.7		

Table VI.B-12.
SMOOTHED FECAL STREPTOCOCCI CONCENTRATIONS BY SAMPLER DISTANCE FROM MICROBIOLOGICAL AEROSOL RUNS

Aerosol Run Number	Run Date	Wastewater Concentration (CFU/100ml)	Aerosol Concentrations (CFU/m³ of air)									Distant Sampler Distance
			Background B	Downwind Concentrations C_d at Sampler Distance d								
				5m	10m	20m	30m	40m	50m	100m	Distant	
M1-6	5-17-76	6.5 x 10^3	0.4	3	0.8	3						
M1-8	5-21-76	20 x 10^3	0.15						0.25			
M1-9	5-24-76	8.0 x 10^3	0.15	6.0	1.6	0.7				0.25		
M1-10	5-24-76	8.0 x 10^3	0.15		4.2	4.0 2.0	2.7		4.7	3.1		
M1-11	5-25-76	2.8 x 10^3	0.6		3.1	5.7 2.7	2.7		1.5			
M1-12	5-27-76	6.8 x 10^3	0.1		15	30 25			13	10		
M1-13	5-27-76	6.8 x 10^3	0.3			1.3 1.7			8.5	0.6		
M1-14	5-27-76	6.8 x 10^3	0.1			14			90	26	6.8	(200m)
M1-15	6-3-76	2.3 x 10^3	0.3		2.1	3.0	2.8		1.8	2.3 1.8		
M1-31	6-14-76	17.1 x 10^3	1.5		3.3	1.9	3.3		3.2 2.1			
M1-33	6-15-76	9.2 x 10^3	0.1			0.5 0.3	0.7	0.55				
M1-34	6-16-76	5.5 x 10^3	0.6			0.8 1.8 4.3	5.1	1.2				
M1-35	6-17-76	4.0 x 10^3	0.3		4.7 4.4	2.7	2.4	3.3	6.5 2.4			
M2-1	1-21-77	9.7 x 10^3	0.4						1.0 1.0	1.8 0.45		
M2-2	1-25-77	4.8 x 10^3	0.3						1.4 0.4	0.9 0.7	0.4	(300m)
M2-3	1-25-77	1.3 x 10^3	2.0						3.3 7.7	8.3 7.3	3.7	(360m)
M2-4	1-30-77	6.0 x 10^3	0.2						1.0 0.7	0.25		
M2-5	1-30-77	12.0 x 10^3	0.3						1.3 1.3	1.0 1.1		
M2-6	2-8-77	3.3 x 10^3	0.1						0.4 0.4	0.2 0.6		
M2-12	2-24-77	1.2 x 10^3	0.01						0.025	1.1 0.4		
M2-13	2-28-77	5.7 x 10^3	0.1						0.4 2.1	0.8 0.6		
M2-14	3-14-77	2.0 x 10^3	0.03						0.3	0.4 0.7	0.1	(490m)
M2-15	3-16-77	7.0 x 10^3	0.01						0.1 0.2	0.6 0.1	0.1	(280m)
M2-16	3-17-77	12.0 x 10^3	0.01						0.8 0.8	0.2 0.4	0.1	(290m)
M2-17	3-18-77	7.2 x 10^3	0.01						0.6 0.3	0.8 0.4		
M2-22	3-25-77	4.3 x 10^3	0.03						0.2			
M2-24	3-26-77	10.0 x 10^3	0.03						0.2 0.4	0.3 0.6	0.1	(420m)
M2-25	3-27-77	11.0 x 10^3	0.025						0.7 0.9	0.1		
M2-29	4-11-77	4.3 x 10^3	0.025							0.175		
M2-31	4-13-77	6.2 x 10^3	0.77						0.85	3.7 1.8		
M2-32	4-14-77	3.0 x 10^3	0.16						0.35			
M2-33	4-19-77	2.2 x 10^3	0.01						0.05	0.1		
M2-34	4-19-77	1.9 x 10^3	0.3						0.4			
M2-35	4-22-77	0.63 x 10^3	0.01						0.2	0.1 0.3		
M2-36	4-23-77	3.0 x 10^3	0.17						0.3 0.3			
M2-37	4-24-77	1.6 x 10^3	0.01						[illegible]	0.2 0.025	0.2	(425m)
M2-38	4-24-77	0.93 x 10^3	0.1						4.9 5.1	1.6 7.0	0.2	(435m)

Table VI.B-13.
SMOOTHED *PSEUDOMONAS* CONCENTRATIONS BY SAMPLER DISTANCE FROM MICROBIOLOGICAL AEROSOL RUNS

Aerosol Run Number	Run Date	Wastewater Concentration (CFU/100ml)	Aerosol Concentrations (CFU/m³ of air)							
			Background B	Downwind Concentrations C_d at Sampler Distance d						
				5m	10m	20m	30m	40m	50m	100m
M1-4	5-13-76	80 x 10^3	4	190	13	33				51
M1-5	5-13-76	80 x 10^3	2	140	1300	330				
M1-6	5-17-76	30 x 10^3	2	430	750	4			6	77
M1-7	5-17-76	30 x 10^3	4			380				77
M1-8	5-21-76	210 x 10^3	15	240	290	235				
M1-9	5-24-76	35 x 10^3	4	140	26				37	
M1-10	5-24-76	35 x 10^3	4		570		150		220	210
M1-11	5-25-76	120 x 10^3	2			83	68		100	30
M1-13	5-27-76	30 x 10^3	4			165			230	15
M1-15	6-3-76	200 x 10^3	2				17		8	9
M1-31	6-14-76	30 x 10^3	2			9	8		9 9	
M1-32	6-15-76	25 x 10^3	1	4						
M1-33	6-15-76	25 x 10^3	1			4.5				
M1-34	6-16-76	30 x 10^3	15			91 76	180	100		
M1-35	6-17-76	20 x 10^3	3.5		250	210	100	260	89 61	

Table VI.B-14.

SMOOTHED *CLOSTRIDIUM PERFRINGENS* CONCENTRATIONS BY SAMPLER DISTANCE FROM MICROBIOLOGICAL AEROSOL RUNS

Aerosol Run Number	Run Date	Wastewater Concentration (MPN/100ml)	Background B	Aerosol Concentrations (MPN/m³ of air) Downwind Concentrations C_d at Sampler Distance d 5m	10m	20m	30m	40m	50m	100m	Distant	Distant Sampler Distance
M1-5	5-13-76	11,000	0.06	5.1	6.0	3.0				5.9		
M1-6	5-17-76	4,600	0.06	2.4	1.0	1.3				2.3		
M1-7	5-17-76	4,600	0.06	1.2								
M1-8	5-21-76	48,000	0.06	0.8		3.3 2.0			1.2 0.8			
M1-9	5-24-76	24,000	0.06	1.9	1.8	1.3			0.23			
M1-10	5-24-76	24,000	0.06		2.3	3.0 1.3	1.9		1.05			
M1-11	5-25-76	4,600	0.06		1.0	0.95			0.5	4.4		
M1-12	5-27-76	4,300	0.06		2.3	3.3 5.0			1.0	0.23		
M1-13	5-27-76	4,300	0.06			1.3 2.3			1.0	0.23	1.8	(200m)
M1-14	5-27-76	4,300	0.06			1.3			2.3	0.45		
M1-15	6-3-76	4,300	0.06		0.9	1.3	1.1		0.33			
M1-31	6-14-76	9,300	0.9		2.7	1.9			1.2 1.2			

Table VI.B-15.

SMOOTHED MYOBACTERIA CONCENTRATIONS BY SAMPLER DISTANCE FROM MICROBIOLOGICAL AEROSOL RUNS

Aerosol Run Number	Run Date	Wastewater Concentration (CFU/100ml)	Background B	Aerosol Concentrations (CFU/m³ of air) Downwind Concentrations C_d at Sampler Distance d 5m	10m	20m	30m	40m	50m	100m
M2-15	3-16-77	11.0×10^3	0.2						11 11	
M2-29	4-11-77	1.0×10^3	0.5						1.15	0.65
M2-30	4-12-77	10.0×10^3	0.1						0.15	0.3 0.7
M2-31	4-13-77	5.0×10^3	0.4						0.5	1.7 1.0
M2-32	4-14-77	7.0×10^3	0.2						0.3 2.3	2.0 1.0
M2-33	4-19-77	7.5×10^3	0.1						2.3 1.0	
M2-34	4-19-77	7.6×10^3	0.15						0.4	1.7 1.0
M2-35	4-22-77	1.0×10^3	0.4						4.3 2.7	1.0 0.7
M2-36	4-23-77	6.0×10^3	0.05						1.7 0.7	1.0 1.0
M2-37	4-24-77	7.3×10^3	0.35						1.0 1.3	1.3
M2-38	4-24-77	5.0×10^3	0.2						11 11	

sol sampling runs and to quantify the sources of variation associated with sampling the microorganism group concentrations.

Tables VI.B-16 through VI.B-23 show the concentration data gathered for Pre-Fair and Post-Fair. The three-day and five-day virus counts were below the detection limit for all samples and the *Clostridium perfringens* levels were also undetected; tables for these groups are not included. Analysis for fecal coliform, *Klebsiella*, and *Pseudomonas* was performed only in Pre-Fair, and the results are shown in Tables VI.B-18, VI.B-21 and VI.B-25. Table VI.B-22 shows the results from the analysis of mycobacteria which was performed only in Post-Fair. Analyses for standard bacterial plate count, total coliform, coliphage, and fecal streptococci were performed in Pre-Fair and Post-Fair periods. The results from these analyses are in Tables VI.B-16, VI.B-17, VI.B-19 and VI.B-20. Also, on the Post-Fair Runs M2-8-9 and M2-27-28, the samples were received by the laboratory at a temperature higher than the specified 4°C.

The 100 mL samples from each sampler on the Pre-Fair and Post-Fair quality assurance runs were divided into portions (usually 25 mL) in the field and then given run numbers. Some of these portions were then divided into smaller parts, called aliquots by the lab. The run numbers and portion numbers are shown in the columns labeled as such. After analysis the data were converted to the measured unit per m^3 of air by the method described in Appendix D using the sampling time and the flow rate. The footnotes used in the quality assurance tables are given in Figure VI.B-2.

d. Virus Runs

Two special virus runs were conducted during the Post-Fair sampling period. Table VI.B-24 shows all of the concentration data gathered from these two runs. Besides being analyzed for enteroviruses, the wastewater and aerosol samples were also checked for standard bacterial plate count, total coliform, fecal streptococci, coliphage, and mycobacteria.

The enterovirus concentrations were about three orders of magnitude lower than coliphage, so a large volume of air had to be sampled. This required the use of high-volume aerosol samplers and special sample concentrating procedures. The special enterovirus runs established the ability to detect enteroviruses in wastewater aerosols and provided a quantitative measure of their concentration coming from a known wastewater aerosol source.

The identifications of the confirmed enterovirus isolates obtained from the aerosol samples on the Post-Fair virus aerosol runs are presented in Table VI.B-25. During Pre-Fair, the single confirmed viral isolate from the 10-meter downwind sampler on Run M1-9 and both confirmed isolates from the upwind sampler on Run M1-12 were identified as poliovirus 1. Since poliovirus 1 was used in the assay laboratory to determine the efficiency of the sample concentration procedure, the Pre-Fair poliovirus 1 isolates may be the result of laboratory contamination and thus are not reported in Table VI.B-25. On virus aerosol Run V2-I, the single confirmed three-day viral isolate was identified as poliovirus 2; of the three confirmed five-day enterovirus isolates, two were identified as poliovirus 2. Of the seven confirmed five-day enterovirus isolates from virus Run V2-II, one was identified as poliovirus 1 and another was identified as coxsackievirus B-3. The process of identifying the remaining confirmed five-day enterovirus isolates from Runs V2-I and V2-II was terminated before completion because of laboratory reorganization. The variety of enteroviruses identified from the aerosol samples of the virus aerosol runs increases the likelihood that the sprayed wastewater was the enterovirus source.

Table VI.B-16.
STANDARD BACTERIAL PLATE COUNTS FROM QUALITY ASSURANCE AEROSOL RUNS

Aerosol Run No.	Run Date	Wastewater Sample (No./100 ml)	Sampler Distance		Aerosol Sample Portion No.	Aerosol Concentrations from Samplers Aligned from Left to Right (No./m^3 of air)											
			From Wet Line Edge	Between Samples													
PRE-FAIR																	
M1-16-19	6-7-76	14×10^6	25 m	1 m	16	16500^d	8000	6000	5000	3600	4000	3600	3300	2700			
					17	7500^d	2900	1700	2000	2500	2000	1900	1600	1900			
					18	6700^d		1700		1900		2500					
M1-20-23	6-8-76	37×10^6	30 m	1 m	20	2800	1700	1400	2300	1800	2400	1600	2100				
					21	2700	1200	1500	2100	2000	2400	1700	2200				
					22		1100		1900		2300		2000				
					23		1300		1300		2000		1600				
M1-24-25	6-9-76	44×10^6	25 m	1 m	24	2600	1500	1200	2000	1300	>89000^k	1600	1900				
M1-26	6-10-76	35×10^6	20 m	1 m	26	1300	1400	1500	>89000^k	1400	27000	1500	1500				
M1-27-30	6-13-76	12×10^6	40 m	1 m	27	4300	930	2000	900	1600	2100	740					
					28	4000	980	2100	1900	1600	12200	740					
					29	6900		1700		3800		1200					
					30	11000		4100		1400		2400					
POST-FAIR																	
M2-18-21	3-22-77	88×10^6	50 m	3 m	18	≥10000^P	280	900	330	1800	5300	530	830	330	600	830	570
							270	870	470	2100	5000	570	1200	370	430	730	570
					19	≥10000^P	530	1100	370	430	10000	500	1200	430	670	1200	700
							670	1300	300	570	9300	500	1400	430	670	1100	570
								1100									
					20	M^l	830	1600	670	320	3700	970	1200	570	1100	2900	830
							570	1700	630	320	3000	1000	1300	670	1000	2800	830
					21	M^l	730	1900	670	430	2800	1500	1500	970	930	8000	1600
							800	1700	670	330		1500	1400	1100	1100	8300	1300

Table VI.B-17.
TOTAL COLIFORM CONCENTRATIONS FROM QUALITY ASSURANCE AEROSOL RUNS

Aerosol Run No.	Run Date	Wastewater Sample (MFC/100 ml)	Sampler Distance		Aerosol Sample Portion No.	Aerosol Concentrations from Samplers Aligned from Left to Right (MFC/m^3 of air)											
			From Wet Line Edge	Between Samples													
Pre-Fair																	
M1-16-19	6-7-76	343 × 10^3	25 m	1 m													
					16	13.2[d]	9.2	7.8	9.8	10.7	4.3	6.3	12.9	4.9			
					17	7.2[d]	15.0	9.1	9.6	5.5	6.7	10.8	5.1	9.3			
					18	8.0[d]		7.6		5.8		7.8					
M1-20-23	6-8-76	127 × 10^3	30 m	1 m													
					20	1.2	1.2	4.2	3.9	0.6	1.2	2.3	3.0				
					21	1.2	1.0	1.2	1.7	0.6	2.4	1.5	1.1				
					22		1.2		3.8		1.2		1.9				
					23		1.9		3.1		3.0		1.6				
M1-24-25	6-9-76	1100 × 10^3	25 m	1 m													
					24	19.5	7.5	14.7	9.6	12.1	22.0	16.1	13.4				
M1-26	6-10-76	758 × 10^3	20 m	1 m													
					26	6.1	9.4	8.9	11.2	8.6	13.0	8.4	13.8				
M1-27-30	6-13-76	267 × 10^3	40 m	1 m													
					27	<0.5	<0.4	0.9	<0.5	<0.6	<0.6	0.7					
					28	<0.5	1.0	<0.5	1.3	<0.6	0.8	<0.5					
					29	<0.5		<0.5		1.0		0.4					
					30	0.7		<0.5		<0.4		<0.5					
Post-Fair																	
M2-18-21	3-22-77	673 × 10^3	50 m	3 m													
					18	8.0[p]	13.3	8.3	7.0	6.7	19.3	10.0	12.7	9.0	8.3	5.3	7.7
						8.3[p]	14.7	8.7	5.3	4.7			8.0	7.3	7.3	5.3	4.0
					19	10.0[p]	8.3	12.7	10.0	9.7	10.0	9.0	8.7	8.7	14.7	11.3	8.0
							10.0	14.7	14.7	13.3	10.0		8.7	9.3	14.0		8.7
					20	M[l]	18.0	15.0	12.7	9.0	11.3	12.0	9.3	10.7	9.7	12.0	10.0
							21.0	14.7	15.3	12.0	10.7	10.0		11.3	12.7	13.3	10.7
					21	M[l]	28.0	23.0	21.0	7.7	22.0	29.0	22.0	22.0	22.0	25.0	15.7
								27.0		6.0	19.3	27.0			21.0		12.7

Table VI.B-18.
FECAL COLIFORM CONCENTRATIONS FROM QUALITY ASSURANCE AEROSOL RUNS

Aerosol Run No.	Run Date	Wastewater Sample (MFC/100 ml)	Sampler Distance		Aerosol Sample Portion No.	Aerosol Concentrations from Samplers Aligned from Left to Right (MFC/m³ of air)								
			From Wet Line Edge	Between Samples										
Pre-Fair														
M1-16-19	6-7-76	60 × 10³	25 m	1 m	16	1.8^d	1.3	0.8	2.4	2.2	0.8	0.3	0.3	0.9
					17	2.4^d	0.7	2.3	<0.3	0.8	1.8	1.2	0.8	5.6
					18	4.4^d		2.7		1.9		2.1		
M1-20-23	6-8-76	14 × 10³	30 m	1 m	20	0.5	<0.3	0.3	0.8	<0.3	0.3	0.3	0.3	
					21	0.4	0.6	0.3	0.2	0.5	0.2	0.6	0.2	
					22		0.5		0.3		<0.2		0.2	
					23		0.2		0.4		0.3		0.2	
M1-24-25	6-9-76	177 × 10³	25 m	1 m	24	3.0	1.1	7.7	2.6	4.3	3.5	7.5	2.0	
M1-26	6-10-76	75 × 10³	20 m	1 m	26	0.9	2.1	2.5	1.6	1.6	1.6	1.7	1.7	
M1-27-30	6-13-76	28 × 10³	40 m	1 m	27	<0.3	<0.3	<0.3	<0.3	<0.3	<0.2	<0.3		
					28	<0.3	<0.3	<0.2	0.2	<0.3	<0.2	<0.2		
					29	<0.3		<0.3		0.3		<0.2		
					30	<0.3		<0.2		<0.2		<0.2		

Table VI.B-19.
COLIPHAGE CONCENTRATIONS FROM QUALITY ASSURANCE AEROSOL RUNS

Aerosol Run No.	Run Date	Wastewater Sample (PFU/ℓ)	Sampler Distance		Aerosol Sample Portion No.	Aerosol Concentrations from Samplers Aligned from Left to Right (PFU/m³ of air)												High Sample Temperature Upon Lab Receipt
			From Wet Line Edge	Between Samples														
PRE-FAIR																		
M1-24-25	6-9-76		25 m	1 m	24	4.3	2.8	2.0	2.0	2.6	2.4^k	2.3	4.1					
M1-26	6-10-76		20 m	1 m	26	1.4	1.8	0.8	1.2	1.4	2.0	2.0	1.3					
POST-FAIR																		
M2-8-9	2-16-77	170×10^3	50 m	3 m	8	0.3	0.5	0.3	0.2	5.9	1.5^i	1.0	0.5	0.5				8°C
					9	0.1		0.3	0.7	2.1			0.3					8°C
M2-27-28	4-5-77	550×10^3	50 m	3 m	27	0.4	0.4	0.9	0.5	0.7	0.2	0.3	0.7	1.0	<0.2	0.4	0.7	9°C
					28		0.3		0.3		0.1		0.4		0.3		0.7	9°C

Table VI.B-20.
FECAL STREPTOCOCCI CONCENTRATIONS FROM QUALITY ASSURANCE AEROSOL RUNS

Aerosol Run No.	Run Date	Wastewater Sample (CFU/100 ml)	Sampler Distance		Aerosol Sample Portion No.	Aerosol Concentrations from Samplers Aligned from Left to Right (CFU/m³ of air)												High Sample Temperature Upon Lab Receipt
			From Wet Line Edge	Between Samples														
PRE-FAIR																		
M1-24-25	6-9-76		25 m	1 m	24	1.8	3.2	0.6	1.1	1.2	2.7	1.5	0.6					
M1-26	6-10-76		20 m	1 m	26	0.6	0.3	0.3	0.3	0.3	0.8	1.1	<0.3					
POST-FAIR																		
M2-8-9	2-16-77	5.0×10^3	50 m	3 m	8	0.4	1.4	≥330	0.7	0.6	0.6^i	1.0	1.0	0.7	2.4			8°C
					9		0.4		0.4		1.1^i		0.7		1.7			8°C
M2-27-28	4-5-77		50 m	3 m	27	0.1	<0.1	1.7	0.4	0.7	1.1	0.1	0.2	0.2	<0.1	<0.1	0.1	9°C
					28	0.2		0.6		3.3		0.3		0.1		<0.1		9°C

Table VI.B-21.
PSEUDOMONAS CONCENTRATIONS FROM QUALITY ASSURANCE AEROSOL RUNS

Aerosol Run No.	Run Date	Sampler Distance		Aerosol Sample Portion No.	Aerosol Concentrations from Samplers Aligned from Left to Right (CFU/m³ of air)							
		From Wet Line Edge	Between Samples									
PRE-FAIR												
M1-24-25	6-9-76	25m	1m									
				24	86	68	101	41	30	118	95	89
M1-26	6-10-76	20m	1m									
				26	190	110	120	30	210	120	160	240

Table VI.B-22.
MYCOBACTERIA CONCENTRATIONS FROM QUALITY ASSURANCE AEROSOL RUNS

Aerosol Run No.	Run Date	Wastewater Sample (CFU/100 ml)	Sampler Distance		Aerosol Sample Portion No.	Aerosol Concentrations from Samplers Aligned from Left to Right (CFU/m³ of air)												High Sample Temperature Upon Lab Receipt
			From Wet Line Edge	Between Samples														
POST-FAIR																		
M2-8-9	2-16-77	1.3 × 10³	50 m	3 m														
					8	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11			8°C
					9a	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11			8°C
					9b	<11	<11	<11	22	<11	<11	<11	<11	<11	<11			8°C
M2-27-28	4-5-77	2.0 × 10³	50 m	3 m														
					27	0.7	<0.3	1.0	<0.3	<0.3	0.3[i]	0.3	0.7	0.7	<0.3	<0.3	0.3	9°C
					28	0.3	0.7	2.0	0.3	1.7	2.3[i]	0.3	0.7	0.3	1.0	0.3	1.0	9°C
					28a	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	9°C
					28b	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	<11	9°C

3. Nature of Aerosol Data

a. *Distributional Characteristics*

This section provides descriptive statistics which help characterize the distributions of the data for each of the microorganism groups. The descriptive statistics are given for values at specified distances because the data analysis is concerned with determining if the spray line is a source of the microorganisms and what effect distance has on the concentrations of the microorganisms.

All the aerosol concentration data in the Appendix F tables are used except underlined (indicating contamination) values, *Klebsiella*, three-day enterovirus, and five-day enterovirus from the Pre-Fair data and Runs 1-26 and 38 for mycobacteria from the Post-Fair data. The data from these groups are not included because very few values are above the detection limit. All data used have been lognormally transformed (lnC).

Table VI.B-23.
KLEBSIELLA CONCENTRATIONS FROM QUALITY ASSURANCE AEROSOL RUNS

Aerosol Run No.	Run Date	Sampler Distance		Aerosol Sample Portion No.	Aerosol Concentrations from Samplers Aligned from Left to Right (CFU/m³ of air)							
		From Wet Line Edge	Between Samples									
PRE-FAIR												
M1-24-25	6-9-76	25 m	1 m	24	2.5	0.3	2.6	4.5	2.0	M^k	0.5	1.4
M1-26	6-10-76	20 m	1 m	26	0.3	1.2	2.2	M^k	0.6	3.5	1.3	1.7

Table VI.B-24.
MICROBIOLOGICAL CONCENTRATIONS ON VIRUS AEROSOL RUNS

Virus Aerosol Run No.	Run Date (Time)	Microbiological Parameter	Concentration	
			Wastewater Sample	Aerosol Sample (50 m)
V2-I	2-26-77 (1505-1733)	Enterovirus–3-day count	23 PFU/ℓ	0.0036 PFU/m³
		Enterovirus–5-day count	45 PFU/ℓ	0.011 PFU/m³
		Standard Plate Count	1.7 × 10^{6} /100 ml	10,000,000 /m³
		Total Coliform	190 × 10^{3} MFC/100 ml	4.6 MFC/m³
		Fecal Streptococci	4.6 × 10^{3} CFU/100 ml	<0.1 CFU/m³
		Coliphage	470 × 10^{3} PFU/ℓ	0.4 PFU/m³
		Mycobacteria	1.3 × 10^{3} CFU/100 ml	<11 CFU/m³
V2-II	4-9-77 (1450-1845)	Enterovirus–3-day count	250 PFU/ℓ	<0.0025 PFU/m³
		Enterovirus–5-day count	330 PFU/ℓ	0.017 PFU/m³
		Standard Plate Count	1.9 × 10^{6} /100 ml	430,000 /m³
		Total Coliform	64 × 10^{3} MFC/100 ml	28 MFC/m³
		Fecal Streptococci	1.0 × 10^{3} CFU/100 ml	0.2 CFU/m³
		Coliphage	370 × 10^{3} PFU/ℓ	1.5 PFU/m³
		Mycobacteria	1.2 × 10^{3} CFU/100 ml	<11 CFU/m³

(S_{lnC}), skewness, and kurtosis. Skewness indicates clustering of the data; if the statistic is negative, the data are clustered to be right of the mean; if positive, clustering is to the left of the mean; if 0 (zero), the data are clustered about the mean. Kurtosis indicates peakedness of the data; a positive value indicates a distribution that is more peaked or narrower than the normal distribution; a negative value indicates a flatter distribution; the normal distribution has zero kurtosis.

The results of the analyses are given in Table VI.B-26 for Pre-Fair and Post-Fair data. For skewness, most of the values are between -1 and 1. These are within the acceptable range for a normal distribution. Small sample sizes (<25) can have a value slightly greater than + 1 and be within the acceptable range. The acceptable range of a normal distribution for kurtosis is about -1.5 to 1.5 for small sample sizes (for sample sizes greater than 50, the range is -1 to 1); most values fall within that range. Large skewness and kurtosis values for several of the groups (such as total coliform at upwind) can be accounted for by the large number of values below the detection limit. Since the log-transformed data usually have a distribution that is approximately normal, the microorganism aerosol concentration data can be considered approximately lognormally distributed.

b. Relative Prevalence

The relative prevalence of the microorganism groups in the wastewater and aerosol samples for Pre-Fair and Post-Fair is indicated by the geometric means or lower detection limit in Table VI.B-27 and by the ratio of the group geometric mean to total coliform geometric mean in Table VI.B-28. The geometric

Figure VI. B-2

FOOTNOTES FOR UNUSUAL EVENTS

Footnotes

a	MPN method used instead of normal assay method.
b	Excessive sampler arcing observed; no data adjustment made.
c	Data adjusted for extreme sampler arcing.
d	Data adjusted for nonstandard volume of air sampled.
e	Data adjusted for sampler power supply problems.
f	Data adjusted for loss of BHI sampler fluid by means other than evaporation.
g	Possible sample contamination; too close to spray line.
h	Possible sample contamination; loss or foaming over of BHI.
i	Possible sample contamination; equipment malfunction (pump/hose readjustment, open top, tubing problems).
j	Possible sample contamination; external sources (vehicle traffic, train dust, wind shift, insects, smoke bomb, cattle too close, operator upwind).
k	Possible sample contamination observed by analysis laboratory.
l	Probable sample contamination; external source (nearby truck or dirt road).
m	Probable sample contamination; equipment malfunction (glass view on plate broken, top opened, tubing broken, contaminated intake).
n	Certain sample contamination; improper cleaning procedures (clorox residual left).
o	Certain sample contamination; improper collection procedures used.
p	Certain sample contamination; sample dropped.
q	No sample collected because sampler developed problems during the run.
r	Sample amount was insufficient for analysis.
s	No analysis performed.
t	No analysis result reported because laboratory observed sample contamination.
u	Analysis results lost.
v	Elevated sample temperature after shipment (8-9°).

means for the aerosol concentrations are listed by distance. Values preceded by a less than (<) sign are the detection limit for the parameter and indicate that the geometric mean of the parameter at that distance is below the detection limit. The ratio of microorganism geometric mean to total coliform geometric mean does not include the upwind values. Values preceded by a less than sign were calculated using the microorganism's detection limit.

For the Pre-Fair downwind data, *Pseudomonas* are 15 times as prevalent as total coliform in the aerosol. Fecal streptococci and *Clostridium perfringens* are between one-third and one-half as prevalent as total coliform in the aerosol. Fecal coliform and coliphage are less prevalent than any of the above three. The *Klebsiella* aerosol concentration detection limit is slightly below the total coliform geometric mean. For the Post-Fair data, mycobacteria is about one and one-half times as prevalent as total coliform in the aerosol. Coliphage and fecal streptococci are about one-third and one-half as prevalent, respectively, as total coliform.

c. *Systematic Sampler Differences*

The testing of the high volume microbiological samplers for collection efficiency at NBL provides a basis for evaluating whether there is need for sampler correction factors to adjust for any collection efficiency bias. The data from the nine runs, as shown in Appendix D, are adjusted for the actual flow

Table VI.B-25.
IDENTIFICATION OF CONFIRMED ENTEROVIRUS ISOLATES FROM AEROSOL SAMPLES

	Post-Fair	
Aerosol Run Number	V2-I	V2-II
Run Date	2-26-77	4-9-77
Sampler Distance	50m	50m
Three-Day Enteroviruses		
Confirmed Isolates	1	0
Poliovirus 1		
Poliovirus 2	1	
Poliovirus 3		
Five-Day Enteroviruses		
Confirmed Isolates	3	7
Poliovirus 1		1
Poliovirus 2	2	
Poliovirus 3		
Coxsackievirus B-3		1
Not Identified*	1	5

* Identification process terminated prior to completion.

Table VI.B-26.

DISTRIBUTIONAL CHARACTERISTICS OF THE NATURAL LOG TRANSFORMED MICROORGANISM GROUP CONCENTRATIONS

PRE-FAIR

Upwind	N	$\overline{\ln C}$	$S_{\ln C}$	Skewness	Kurtosis[1]
Std. Bacterial Plate Count	18	6.692	1.360	-0.280	-1.031
Total Coliform	19	-1.357	0.691	2.393	6.658 [2]
Fecal Coliform	16	-1.657	0.474	0.264	-0.777
Coliphage	18	-2.557	0.531	1.486	0.545
Pseudomonas	15	2.516	1.159	1.805	2.324
Fecal Streptococci	16	-0.720	0.935	1.244	1.392
Clostridium perfringens	17	-0.672	0.061	2.373	3.633 [2]
5-20 m Downwind					
Std. Bacterial Plate Count	43	7.861	0.683	0.200	-1.031
Total Coliform	53	1.744	1.335	-0.243	-0.134
Fecal Coliform	47	0.003	1.250	0.055	-0.829
Coliphage	53	-1.069	1.136	0.070	-0.940
Pseudomonas	38	4.270	2.102	0.168	-1.138
Fecal Streptococci	52	0.365	1.175	0.732	-0.226
Clostridium perfringens	49	0.376	0.940	-0.050	-1.112
30-50 m Downwind					
Std. Bacterial Plate Count	29	7.355	0.877	-0.982	1.439
Total Coliform	29	0.889	1.504	0.268	-0.481
Fecal Coliform	29	-1.004	1.074	0.803	0.038
Coliphage	31	-1.441	1.186	0.195	-1.323
Pseudomonas	25	3.525	1.555	0.165	-1.411
Fecal Streptococci	32	0.528	1.239	0.904	1.494
Clostridium perfringens	23	-0.086	0.619	1.167	1.662
100-200 m Downwind					
Std. Bacterial Plate Count	16	6.784	0.832	0.092	1.253
Total Coliform	17	0.179	1.205	-0.168	-1.636
Fecal Coliform	12	-1.437	0.503	0.095	-0.907
Coliphage	17	-1.729	0.732	0.056	-0.637
Pseudomonas	11	3.766	1.693	0.824	0.169
Fecal Streptococci	14	0.676	1.336	0.653	-0.731
Clostridium perfringens	16	0.065	0.891	0.471	-1.203

---

1 - 3 is subtracted

2 - The high skewness and kurtosis for these parameters can be attributed to the number of runs below the detection limit.

rates from the pin-wheel anemometer test, and an average value calculated for each sampler tested. These are shown in Table VI.B-29.

The sample variance among these sample means is $S^2 = 11{,}606.9$. For comparison, the nine values for Sampler 7 are used to calculate an S^2 of 5,657.0, and an F-test gives a ratio of 2.05 with 7 and 8 df.

Table VI.B-26. (cont'd)

POST-FAIR

Upwind	N	$\overline{\ln C}$	$S_{\ln C}$	Skewness	Kurtosis[1]
Std. Bacterial Plate Count	24	5.711	1.417	-.220	-1.003
Total Coliform	25	-2.104	.698	3.249	8.896 [2]
Coliphage	28	-2.857	.434	3.038	7.867 [2]
Fecal Streptococci	29	-1.871	1.363	1.058	.142
Mycobacteria	9	-1.190	.964	.898	-.592

50 m Downwind					
Std. Bacterial Plate Count	45	6.104	1.308	-.103	-1.153
Total Coliform	56	.912	1.374	-.666	.295
Coliphage	56	-.722	1.014	-.371	-.088
Fecal Streptococci	55	-1.077	1.360	.083	-.643
Mycobacteria	18	-.219	1.022	-.177	-1.106

100 m Downwind					
Std. Bacterial Plate Count	48	5.803	1.239	.215	-.763
Total Coliform	56	-.441	1.499	.059	-1.180
Coliphage	55	-1.479	1.041	-.057	-1.205
Fecal Streptococci	57	-1.243	1.417	.438	-.437
Mycobacteria	18	-.201	.966	-.468	-.113

Distant Downwind					
Std. Bacterial Plate Count	76	5.865	1.404	-.216	-.505
Total Coliform	85	-2.072	.524	2.832	7.983 [2]
Coliphage	81	-2.778	.554	2.694	6.231 [2]
Fecal Streptococci	85	-1.863	1.213	.780	-.460
Mycobacteria	27	-.710	.932	-.105	-1.414

---

1 - 3 is subtracted

2 - The high skewness and kurtosis for these parameters can be attributed to the number of runs below the detection limit.

Table VI.B-27.
GEOMETRIC MEANS AND RATIOS OF WASTEWATER AND AEROSOL CONCENTRATIONS OF MICROORGANISM GROUPS

	Geometric Mean Wastewater Conc. (#/ml)	Geometric Mean Aerosol Concentrations (#/m^3 of Air)					Aerosol/Wastewater Ratio of Geometric Mean Concentration		
Pre Fair Runs		Upwind	5-20 m	30-50 m	100-200 m		5-20 m	30-50 m	100-200 m
Standard Plate Count	699,000	805	2590	1560	880		0.0037	0.0022	0.0013
Total Coliform	7,500	<0.5	5.7	2.4	1.2		0.0008	0.0003	0.0002
Fecal Coliform	800	<0.3	1.00	0.37	<0.3		0.0013	0.0004	<0.0004
Coliphage	220	<0.1	0.34	0.24	0.18		0.0012	0.0007	0.0008
Fecal Streptococci	67	<0.6	1.4	1.7	1.9		0.021	0.025	0.028
Pseudomonas	1,050	<15	72	34	43		0.068	0.032	0.041
Klebsiella	390	<5	<5	<5	<5		<0.01	<0.01	<0.01
Clostridium perfringens	54	<0.9	1.5	0.9	1.1		0.027	0.017	0.020
3-Day Enterovirus	0.012	<0.2	<0.2	<0.2	<0.2		<10	<10	<9
5-Day Enterovirus	0.017	<0.2	<0.2	<0.2	<0.2		<7	<7	<6
Post Fair Runs		Upwind		50 m	100 m	Distant	50 m	100 m	Distant
Standard Plate Count	158,000	300		450	330	380	0.0028	0.0021	0.0022
Total Coliform	4,900	<0.2		2.52	0.59	<0.2	0.0005	0.0001	<0.00004
Coliphage	290	<0.1		0.51	0.23	<0.1	0.0017	0.0008	<0.0003
Fecal Streptococci	34	0.15		0.34	0.29	0.15	0.0100	0.0085	0.0044
Mycobacteria	46	0.30		0.80	0.82	0.51	0.0176	0.0178	0.0110
3-Day Enterovirus	0.076			0.002			0.026		
5-Day Enterovirus	0.12			0.014			0.11		

Table VI.B-28.
RELATIVE PREVALENCE OF MICROORGANISM GROUPS

	Ratio of Group Geometric Mean to Total Coliform Geometric Mean	
Pre Fair Runs	Wastewater (#/ml)/(MFC/ml)	Downwind Aerosol (#/m^3)/(MFC/m^3)
Std. Bacterial Plate Count	93.4	530
Total Coliform	1.000	1.000
Fecal Coliform	1.106	0.174
Coliphage	0.030	0.061
Fecal Streptococci	0.009	0.47
Pseudomonas	0.140	15.2
Klebsiella	0.052	<0.78
Clostridium perfringens	0.007	0.359
3-Day Enterovirus	0.000002	<0.035
5-Day Enterovirus	0.000002	<0.035
Post Fair Runs		
Std. Bacterial Plate Count	32.6	788
Total Coliform	1.000	1.00
Coliphage	0.060	0.35
Fecal Streptococci	0.0070	0.49
Mycobacteria	0.0094	1.41
3-Day Enterovirus	0.000016	0.0008
5-Day Enterovirus	0.000024	0.006

Table VI.B-29.
MEAN NORMALIZED FLAVOBACTERIUM COUNTS, ADJUSTED FOR FLOW RATE (CFU/l)

Sampler							
1	5	6	7	8	9	10	11
288	544	503	297	270	423	475	432

This is not a significant value; thus, there is no indication of a need for a sampler correction factor.

The aerosol data for indicator microorganisms from the Pre-Fair quality assurance aerosol runs are used to further investigate the need for a correction factor for a sampler bias. An ANOVA is performed for each type of data on each run with samplers and portions as factors. Only the PEL analyses are used, because the additional factor of laboratories could interfere with the analysis. The F-ratios are summarized in Table VI.B-30.

For the total coliform and fecal coliform data, no significant F-ratios are obtained. The standard bacterial plate count data provide two significant F-ratios, however, and these are investigated further.

From Run M1-20-23 a means separation technique is used to determine which samplers are different. From this, it is determined that Sampler 1 is higher than all the others, which can be considered equivalent. On Run M1-27-30, a similar analysis shows that Samplers 8 and 10 are high, relative to the others. However, some of these high values were subsequently identified as affected by sampler contamination by the usual contamination inference procedure, so that the significant F-ratios may be due to contaminated samplers.

From the above, the conclusion drawn is that no systematic bias exists among the samplers. In general, variation among samplers is no greater than can be explained by sample-to-sample variation, and where a sampler term is significant, the usual contamination inference procedure often deletes the value prior to data analysis. Thus, there is no evidence of a need for a bias correction factor.

4. Aerosol Measurement Precision from Quality Assurance Program

Inspection of the dye and microbiological aerosol concentration data in Appendix F shows considerable variation, even between paired samplers. Special quality assurance aerosol runs (Tables VI.B-16 through VI.B-23) were conducted to more carefully determine the uncertainty in an aerosol concentration measurement for each microorganism group. After the quality assurance runs, several aliquots were sometimes analyzed from up to four separate portion bottles each containing the BHI sample collection fluid from one of many samplers placed side-by-side at the same distance from the wet-line edge. Therefore, it is of practical value to determine the total uncertainty in an aerosol concentration measurement (measurement variation), that fraction of measurement variation retained in the portions (portion variation), and that fraction of the portion variation retained in the aliquots (aliquot variation). Measurement variation results from differing levels of the microorganism sampled by the samplers, variation in sampler operator procedures, undetected sampler contamination, bottle variation, shipping variation, analytical technique of the laboratory

Table VI.B-30.
SUMMARY OF F-RATIOS

Aerosol Run No.	Analysis Parameter	F	df		Significance Level
			f_1	f_2	
16–19	Total Coliform	0.96	8	13	OK
	Fecal Coliform	0.79	8	13	OK
	Plate Count	1.78	8	13	OK
20–23	Total Coliform	2.34	7	16	OK
	Fecal Coliform	0.75	7	16	OK
	Plate Count	7.9	7	16	<0.005
27–30	Total Coliform	0.41	6	15	OK
	Fecal Coliform	1.20	6	15	OK
	Plate Count	3.10	6	15	0.05

doing the analysis, and random error. Because portions were taken from the same sample, but submitted to the laboratory on the quality assurance runs as being different, portion variation is due to bottle variation, shipping variation, analytical technique variation, and random error. Aliquots are taken from the same portion during sample preparation by the laboratory; therefore, aliquot variation is due to random error in the analytical measurement process.

The appropriate random effects model for the full nested design (aliquots k within portions j with samplers i) occurring on some quality assurance runs is

$$X_{ijk} = \mu + A_i + B_j + \varepsilon_{ijk} \qquad (1)$$

Sampler $i = 1, \ldots, a$ $\quad A_i \frown N(0, \sigma_A)$

Portion $j = 1, \ldots, b_i$ $\quad B_j \frown N(0, \sigma_B)$

Aliquot $k = 1, \ldots, m$ $\quad \varepsilon_{ijk} \frown N(0, \sigma)$

Then in terms of the preceding definitions, the measurement variation variance is $\mathrm{Var}(X_{ijk}) = \sigma_A^2 + \sigma_B^2 + \sigma^2$, while the portion variation variance is $\sigma_B^2 + \sigma^2$, and the aliquot variation variance is σ^2.

On most quality assurance runs, one aliquot of each portion from each sampler was analyzed and reported separately. The standard analysis of variance of this nested design would yield mean square estimates of the "between sampler" and "within sampler" sources of variation. The within sampler mean square does estimate the variance due to portion variation, $\sigma_B^2 + \sigma^2$. However, the between sampler mean square must be suitably adjusted and combined to yield an estimate of the measurement variation, $\sigma_A^2 + \sigma_B^2 + \sigma^2$.

The analysis of distributional characteristics in Section VI.B.3 suggests that the aerosol concentration data for each microorganism group may be considered to follow a lognormal distribution. When replicate measurements are made at each of several levels i to estimate the true values μ_i for a log-normally distributed variable, then the true coefficient of variation $\beta_i = \sigma_i/\mu_i$ for each grouped data set is the same value β ((30)). Thus, a coefficient of variation analysis ((31)) is used to estimate and report each type of variation.

In a coefficient of variation analysis, the coefficient of variation is estimated over k groups of size n_i $(x_1, x_2 \ldots, x_{n_i})$ as

$$\hat{\beta} = \sum_{i=1}^{k} w_i \hat{\beta}_i / k = \sum_{i=1}^{k} w_i(\alpha_i s_i / \bar{x}_i)/k \qquad (2)$$

where $\bar{x}_i$ = sample mean of group $i = \Sigma x/n$

s_i = sample standard deviation of group $i = [\Sigma (x - \bar{x}_i)^2 / (n - 1)]^{1/2}$

α_i = bias correction factor $= (2/n_i)^{1/2}\Gamma(n_i/2)/\Gamma[(n_i - 1)/2]$

$\hat{\beta}_i$ = sample coefficient of variation of group $i = \alpha_i s_i/\bar{x}_i$

w_i = group weight $\propto n_i/\alpha_{n_i}^2$; $\Sigma w_i = k$

The bias correction factor α_i adjusts for the bias in the sample standard deviation s_i as an estimator of the population standard deviation σ_i ((32)) Zeigler ((33)) tabulates these correction factors, which approach 1.0 as the sample size increases: $C_2 = 1.253$, $C_3 = 1.128$, $C_4 = 1.058$, $C_8 = 1.036$, and $C_{20} = 1.013$. The weights w_i are computed ((34)) to be proportional to the inverse of the variance of the group estimator $\hat{\beta}_i = \alpha_i s_i/\bar{x}_i$. In a coefficient of variation analysis, the estimates $\hat{\beta}_i$ are ordered by increasing group mean $\bar{x}_i$ and tabulated to check the assumption that β_i is independent of μ_i.

In the aerosol measurement precision analysis, most groups consisted only of a single pair of concentration measurements. To facilitate presentation of the analysis, similar pairs were combined via equation (2) and tabulated as a single group. In such cases, the arithmetic mean was taken as the group mean for a quality assurance run group (when the true mean was presumably the same), and the geometric mean was used as the group mean for basically unrelated pairs (e.g., all Post-Fair pairs at 50 meters).

a. *Dye Aerosol Concentrations*

(1) Dye Analysis Accuracy

To ensure that the dye measurements made on both the wastewater and the aerosol dye samples were representative of the true concentration, a study was conducted using simulated samples at known concentrations. The samples were prepared using a basic stock solution of dye and the medium in which the actual samples would be analyzed, i.e., deionized water for the aerosol samples, and wastewater for the run composite samples. Samples were randomized to ensure that the analyst did not know at which level he was working.

For the aerosol simulation, a total of 18 sample portions were prepared, with 2 blanks and 4 portions at each of 4 concentrations: 1.8, 18, 72 and 360 μg/l. The values obtained are shown in Table VI.B-31. For each level, the mean and standard deviation are calculated and a 95-percent confidence interval constructed. The measurements are said to be accurate if the actual value falls within the confidence limits shown.

As can be seen, the measurements satisfy the accuracy criterion above at all levels. However, in all cases there is slight positive bias. On a relative basis, this ranges from 1.6 to 4.2 percent of the true value, and averages 2.5 percent. However, this is within the limits of the precision of the determination.

Similarly, 4 portions of wastewater were prepared at an actual level of 59,500 to represent the run composite samples taken. These were submitted to the same analysis as the samples above and the results are summarized in Table VI.B-32. The actual concentration was unknown to the analyst.

As in the previous study, the confidence interval contains the actual value of the sample, and thus can be said to be accurate. The bias is calculated as before and is similar to that found in the simulated aerosol samples. The possibility thus exists that there is a slight, 2 to 3-percent, high-side bias in the measurements, but with only 4 portions analyzed at a given level, there is insufficient information to ascertain this using ordinary parametric tests.

A chi-square test can be used to give further information, however. If the differences are calculated between each determined value and the actual value, it is noted that of the 20 non-blank determinations, 3 is equal to, 2 are less than, and the remaining 15 are greater than the actual value. For the deter-

Table VI.B-31.
DYE ACCURACY RESULT SUMMARY, SIMULATED AEROSOL SAMPLES

Sample No.	Actual Level, (μg/l) 0	1.8	18	72	360
1	0.0	1.5	18.5	74.0	360
2	0.0	2.0	18.5	72.5	361
3	–	2.0	18.5	74.0	380
4	–	2.0	18.0	72.0	370
Mean	0.0	1.88	18.38	73.13	367.75
Std Dev	0.0	0.25	0.25	1.03	9.32
95% CI	–	(1.48, 2.28)	(17.98, 18.78)	(71.49, 74.77)	(352.92, 382.58)
Bias, %	0.0	4.2	2.1	1.6	2.2

Table VI.B-32.
DYE ACCURACY RESULT SUMMARY, SIMULATED EFFLUENT SAMPLES (μg/l)

Sample No.	Actual Value, 59,500
A	60,000
B	60,800
C	58,000
D	60,000
Mean	59,700
Std Dev	1,194
95% CI	(57,800, 61,600)
Bias, %	3.4

minations to be accurate, approximately equal numbers should fall above and below the true value, or 8.5, discounting the equal values. A test of significance is used to determine the likelihood of obtaining a 2 and 15 split if the expected number of each were actually 8.5. The chi-square statistic has a value of 9.94 with 1 degree of freedom, and this gives a significance level of about 0.002. Thus there is evidence that the bias is real, though slight. The indicated 2-percent positive bias in both the wastewater and aerosol dye concentrations will have no net effect on aerosolization efficiency estimates because of cancellation (see equation (4) of Section VI.C).

(2) Dye Measurement Precision

A preliminary scan of the paired values in the dye run plots of Figure VI.B-1 suggests that the magnitude of the paired value variability is approximately proportional to the average of the paired dye levels. When the sample standard deviation is proportional to the sample mean, the coefficient of variation approach is an appropriate analysis methodology. Coefficients of variation were computed to estimate the measurement variation from the paired samplers on the dye runs. Separate estimates were calculated for the Pre-Fair pairs, the Post-Fair sets at 50 meters (after adjusting for diffusion concentration D), the Post-Fair pairs at 75 meters, and the Post-Fair pairs at 100 meters. The portion coefficient of variation was estimated from the aerosol simulation in the dye accuracy study (Table VI.B-31).

The dye measurement and portion coefficients of variation are presented in Table VI.B-33. The measurement coefficient of variation estimates appear to be nearly constant over the aerosol concentration range of 0.1 to 2.5 $\mu g/m^3$. A weighted dye measurement coefficient of variation of 0.17 = 17 percent was obtained using equation (2). The measurement coefficient of variation is considerably larger than the portion coefficient of variation (5 percent). Most of the dye measurement variation appears to be due to sampling factors (and perhaps to localized aerosol concentration anomalies), rather than to analytical factors.

b. Microbiological Aerosol Concentrations

Because no techniques of preparing microbiological samples of a known stable concentration were available, the accuracy of microbiological aerosol measurements could not be determined. The lognormally distributed nature of the aerosol concentration data for each microorganism group indicates that a coefficient of variation analysis is warranted to estimate the precision of the aerosol measurement process. The precision has been determined for each microorganism group in terms of measurement variation, portion variation, and aliquot variation, when appropriate, for each quality assurance aerosol run and for suitable groups of paired samples from the microbiological aerosol runs.

All of the applicable aerosol concentration data, except those values inferred to have been affected by sample contamination, were used in calculating the precision variation. The single exception was that the calculation of measurement and portion variation for standard bacterial plate count and total coliform on quality assurance Run M2-18-21 was only based on portions 18 and 19. The data for this run (see Tables VI.B-16 and VI.B-17) show a general increasing trend with portion number for most samplers. The portions were refrigerated until analysis was begun. Total coliform analyses were prepared over a three-hour period in the morning and standard bacterial plate count analyses were prepared over a two-hour period in the afternoon. The portion bottles were removed from the refrigerator at the beginning of the analysis period and prepared sequentially starting with portion 18. The increased levels in standard bacterial plate count and total coliform for portions 20 and 21 from each sampler (often exceeding a factor of 2) is apparently due to the lengthened exposure to room temperature prior to analysis. It should be noted that the preparation duration on M2-18-21, in which 48 aerosol sample portions were analyzed, exceeded those of the other quality assurance runs and any microbiological aerosol run (typically, eight aerosol sample portions).

The microbiological aerosol concentration precision results are presented in Tables VI.B-34 (standard bacterial plate count), VI.B-35 (total coliform), VI-B-36 (fecal coliform), VI.B-37 (fecal streptococci), VI-B-38 (coliphage), and VI.B-39 (pathogens - *Pseudomonas*, mycobacteria, *Klebsiella*, and *Clostridium perfringens*). When the measured aerosol concentrations are sufficiently above the detection limit, the measurement variation of a microorganism group tends to have a constant coefficient of variation, regardless of the run group mean. This can be seen especially for total coliform above 3 MFC/m^3 in Table VI.B-35 and for fecal streptococci above 0.6 CFU/m^3 in Table VI.B-37. Nearer the detection limit, the precision coefficients of variation tend to be higher because the sampling resembles a Poisson process with few events per interval.

Weighted estimates of the precision coefficients of variation calculated using equation (2) are provided on the bottom line of the precision tables. These weighted estimates indicate the extent of variation of each type for the microorganism group over the aerosol concentration range examined. Thus, for example, the precision coefficients of variation for total coliform in aerosols over the range from 0.4 to 14 MFC/m^3 were 0.50 for measurement variation, 0.49 for portion variation, and 0.15 for aliquot variation. This means that the standard deviation of a total coliform aerosol measurement due to all sources of uncertainty in the measurement process is about 0.50 = 50 percent of the true aerosol concentration (which is best estimated by

Table VI.B-33.
DYE AEROSOL CONCENTRATION PRECISION

RUN GROUP	MEAN (µg/m^3)	COEFFICIENT OF VARIATION: MEASUREMENT VARIATION	COEFFICIENT OF VARIATION: PORTION VARIATION
Post-Fair at 100m	0.17	0.21	
Post-Fair at 75m	0.25	0.15	
Post-Fair at 50m	0.44	0.18	
Pre-Fair Pairs	2.5	0.15	
Dye Accuracy Study	---		0.05
WEIGHTED ESTIMATE		0.17	0.05

Table VI.B-34.
STANDARD BACTERIAL PLATE COUNT AEROSOL CONCENTRATION PRECISION

RUN GROUP	MEAN (No./m^3)	COEFFICIENT OF VARIATION MEASUREMENT VARIATION	PORTION VARIATION	ALIQUOT VARIATION
Post-Fair at 100m	330	0.54		
Post-Fair at 50m	620	0.46		
QA:M2-18-21	740	0.60	0.36	0.11
QA:M1-26	1430	0.06		
Pre-Fair Pairs	1700	0.31		
QA:M1-24-25	1730	0.29		
QA:M1-20-23	1890	0.27	0.12	
QA:M1-27-30	2690	0.98	0.49	
QA:M1-16-19	3100	0.56	0.59	
WEIGHTED ESTIMATE		0.50	0.37	0.11

the concentration value obtained). In a portion, the standard deviation of the uncertainty in the analyzed total coliform value is about 0.49 = 49 percent of the value. In an aliquot, the standard deviation of the uncertainty in the analyzed value is about 0.15 = 15 percent of its value.

The weighted estimates for the microorganism groups are presented in Table VI.B-40; the groups are arranged by increasing measurement coefficient of variation. The microbiological aerosol measurement variation for each of the microorganism groups is much greater than the dye aerosol measurement variation. The microbiological portion variations are also much greater than the dye portion variation. Thus, there is much less precision in the microorganism aerosol concentrations than in the dye aerosol concentrations. Grouping of the microorganisms by measurement variation in Table VI.B-40 shows better precision for total coliform and standard bacterial plate count than for fecal coliform, *Pseudomonas*, and *Clostridium perfringens*. Aerosol measurement of mycobacteria, fecal streptococci, *Klebsiella*, and coliphage has the least precision. Microbiological aerosol measurement precision seems to improve as expected when the measurements consistently exceed the detection limit and when the more routine measurements are made.

By making the assumption that measurement variation and portion variation were calculated for the same distribution of aerosol concentrations, one can quantify the contributions of analytical sources of variation and of field sampling sources of variation to the total measurement variation. Under this assumption, the square of the measurement variation equals the sum of the squares of portion variation (representing shipping and analytical sources) and of sampling variation (representing field sampling sources). The sampling variation thus obtained is shown in Table VI.B-40. Comparing the relative magnitudes of sampling variation and portion variation shows that the dye measurement variation is mostly due to field sampling sources.

Table VI.B-35.
TOTAL COLIFORM AEROSOL CONCENTRATION PRECISION

RUN GROUP	MEAN (MFC/m^3)	COEFFICIENT OF VARIATION MEASUREMENT VARIATION	PORTION VARIATION	ALIQUOT VARIATION
QA:M1-27-30	0.4	0.85	0.84	
Post-Fair at 100m	1.0	0.65		
QA:M1-20-23	1.9	0.55	0.37	
Pre-Fair Pairs	2.5	0.57		
Post-Fair at 50m	3.0	0.37		
QA:M1-16-19	8.5	0.37	0.38	
QA:M2-18-21	9.9	0.34	0.35	0.15
QA:M1-26	9.9	0.27		
QA:M1-24-25	14.4	0.35		
WEIGHTED ESTIMATE		0.50	0.49	0.15

Table VI.B-36.
FECAL COLIFORM AEROSOL CONCENTRATION PRECISION

RUN GROUP	MEAN (MFC/m^3)	COEFFICIENT OF VARIATION MEASUREMENT VARIATION	PORTION VARIATION
QA:M1-20-23	0.3	0.47	0.49
Pre-Fair Pairs	0.8	0.46	
QA:M1-16-19	1.7	0.84	0.83
QA:M1-26	1.7	0.27	
QA:M1-24-25	4.0	0.64	
WEIGHTED ESTIMATE		0.58	0.65

Table VI.B-37.
FECAL STREPTOCOCCI AEROSOL CONCENTRATION PRECISION

RUN GROUP	MEAN (CFU/m^3)	COEFFICIENT OF VARIATION MEASUREMENT VARIATION	COEFFICIENT OF VARIATION PORTION VARIATION
QA:M1-26	0.5	0.74	
QA:M2-27-28	0.5	1.47	0.81
Post-Fair at 100m	0.6	0.78	
Post-Fair at 50m	0.6	0.55	
QA:M2-8-9	0.9	0.64	0.52
QA:M1-24-25	1.6	0.62	
Pre-Fair	2.0	0.58	
WEIGHTED ESTIMATE		0.77	0.67

Table VI.B-38.
COLIPHAGE AEROSOL CONCENTRATION PRECISION

RUN GROUP	MEAN (PFU/m^3)	COEFFICIENT OF VARIATION MEASUREMENT VARIATION	COEFFICIENT OF VARIATION PORTION VARIATION
Post-Fair at 100m	0.3	0.88	
Pre-Fair Pairs	0.3	0.87	
QA:M2-27-28	0.5	0.63	0.51
Post-Fair at 50m	0.5	0.56	
QA:M2-8-9	1.0	1.32	0.63
QA:M1-26	1.5	0.29	
QA:M1-24-25	2.8	0.33	
WEIGHTED ESTIMATE		0.73	0.56

In contrast, for each microorganism group, the portion variation is larger than the sampling variation. Shipping and analytical sources are apparently responsible for more of the microorganism aerosol measurement variation than are the field sampling sources. For total coliform and standard bacterial plate count, aliquot variation represents only a small part of the portion variation; for these microorganism groups, most of the "shipping and analytical variation" is attributable to factors such as bottles, analysts, and day-to-day procedural variations rather than to variations in repeated analyses. The differences in Table VI.B-40 between measurement variation, portion variation, and the more frequently reported aliquot variation emphasize the need for quality assurance runs and pairing of samplers if one is to accurately estimate aerosol measurement precision and assess its contributing factors.

Table VI.B-39.
PATHOGEN AEROSOL CONCENTRATION PRECISION

MICROORGANISM GROUP RUN GROUP	MEAN (CFU/m^3)	COEFFICIENT OF VARIATION MEASUREMENT VARIATION	 PORTION VARIATION
PSEUDOMONAS			
Pre-Fair Pairs	22	0.82	
QA:M1-24-25	79	0.40	
QA:M1-26	150	0.47	
Pseudomonas Weighted Estimate		0.58	
MYCOBACTERIA			
QA:M2-27-28	0.6	0.86	0.92
Post-Fair at 100m	1.0	0.59	
Post-Fair at 50m	1.4	0.86	
Mycobacteria Weighted Estimate		0.81	0.92
KLEBSIELLA			
QA:M1-26	1.6	0.73	
QA:M1-24-25	2.0	0.76	
Klebsiella Weighted Estimate		0.74	
CLOSTRIDIUM PERFRINGENS			
Pre-Fair Pairs	1.5 MPN/m^3	0.60	

Table VI. B-40.
AEROSOL CONCENTRATION PRECISION SUMMARY

	Coefficient of Variation			
MICROORGANISM GROUP	Total (Measurement Variation)	Sampling (Sampling Variation)	Analytical (Portion Variation)	Replication (Aliquot Variation)
Dye	17%	16%	5%	
Total Coliform	50%	9%	49%	15%
Standard Bacterial Plate Count	50%	34%	37%	11%
Fecal Coliform	58%	Little	65%	
Pseudomonas	58%			
Clostridium perfringens	60%			
Coliphage	73%	46%	56%	
Klebsiella	74%			
Fecal Streptococci	77%	39%	67%	
Mycobacteria	81%			

5. Particle Size Distributions

The data available for particle size analysis come from Phase I of the program. A more extensive study of particle size using six-stage Andersen samplers was planned for Phase II, but had to be deleted because of funding limitations. In the Phase I sampling, two-stage Andersen samplers were used to obtain the samples, with the size ranges of >7.0 μm (Stage I) and 1.05-7.0 μm (Stage II), which roughly correspond to nonrespirable and respirable particles, respectively. While some information is obtained on the distribution, it is less definitive than would have been available using the six-stage sampler. However, the purpose of the aerosol runs made with these samplers in Phase I was not originally aimed to obtain particle size data. In some instances, the purpose was to determine the correct times for the aerosol sampling in subsequent phases of the program. On other runs, the Andersen sampler was paired with AGI and LEAP samplers to allow an evaluation of the different means of obtaining aerosol samples. This breakout of the data by size is intended only to give a general idea of the distribution and to provide comparative data with other studies.

Two collection media were used in the Phase I study: EMB agar for total coliform and Casitone agar for total count. The summary of the total coliform results is shown in Table VI.B-41, while for total count the results are shown in Table VI.B-42. For those counts that fell either above or below the detection limit, no percentage calculation was made. It should be noted that not all the runs made during Phase I are summarized here. If the number of usable results was small, or in some cases nonexistent, the run was not included in these summaries.

The particle size distributions for total coliform and total count are shown in Tables VI.B-43 and VI.B-44, respectively. For purposes of summarizing the results, the upwind samples and those beyond 200 meters for total count and beyond 100 meters for total coliform are considered to represent background levels. The results are summarized as percent respirable (1.05-7.0 μm).

For total count, the percent of the total number of particles which can be considered to be respirable range from a low of 14 percent to a high of 76 percent for the background. The median percent was 43.5 with a mean value of 43.6 percent, based on 20 values. The total count particle size distribution is broken down into two ranges for further study; close downwind (5 to 25 meters) and far downwind (50 to 200 meters). The close downwind results gave a range from 65 percent respirable to 76 percent respirable, based on four results. The median was 70 percent with a mean of 70.2 percent. The far downwind results had ten data points, ranging from 20 percent to 74 percent respirable. The median for this data set was 43 percent, with a

Table VI.B-41.
AEROSOL PARTICLE SIZE DISTRIBUTION FROM TWO-STAGE ANDERSEN SAMPLERS—TOTAL COLIFORM (No./m³)

Run	Distance	Stage I (Non-Respirable)	Stage II (Respirable)
7	100	1.4×10^2	3.9×10^2
	100	1.1×10^1	2.0×10^2
8	u	7.7×10^1	$>2.4 \times 10^2$
	20	1.4×10^2	6.0×10^2
	20	1.3×10^2	6.4×10^2
	75	7.1×10^1	4.9×10^2
	75	2.8×10^1	5.6×10^1
	75	3.5×10^1	1.4×10^1
	390	$<3.5 \times 10^1$	7.1×10^2
	390	2.1×10^1	1.4×10^2
	390	4.7×10^1	9.4×10^1
9	u	1.7×10^2	1.7×10^2
	u	1.1×10^2	8.0×10^1
	825	3.5×10^1	1.4×10^1
	825	1.9×10^1	1.6×10^1
	825	3.5×10^1	1.9×10^1
10	500	$<2.0 \times 10^0$	$<2.0 \times 10^0$
	500	2.1×10^2	8.5×10^1
	500	5.9×10^1	—
	1500	1.5×10^2	3.5×10^2
	1500	—	4.9×10^1
	1600	$<3.5 \times 10^1$	$<3.5 \times 10^1$
	1600	1.4×10^1	4.2×10^1
	1600	2.0×10^0	2.4×10^1
11	1	$<7.1 \times 10^1$	$<7.1 \times 10^1$
	1	1.1×10^2	1.8×10^2
	1	2.8×10^1	6.4×10^1
	1	$<2.0 \times 10^0$	1.6×10^1
	1600	$<7.0 \times 10^0$	$<7.0 \times 10^0$
	1600	2.0×10^0	5.0×10^0

Note: u = upwind.

Table VI.B-42.
AEROSOL PARTICLE SIZE DISTRIBUTION FROM TWO-STAGE ANDERSEN SAMPLERS—TOTAL COUNT

Run	Distance, m	Stage I (Non-Respirable)	Stage II (Respirable)
1	u	1.6×10^{1}	5.0×10^{0}
	5	4.2×10^{2}	1.0×10^{3}
	25	9.9×10^{2}	2.3×10^{3}
	50	4.2×10^{2}	2.6×10^{2}
	100	4.7×10^{1}	1.2×10^{1}
	150	7.0×10^{0}	$<7.0 \times 10^{0}$
2	u	4.7×10^{1}	1.3×10^{1}
	10	6.4×10^{0}	1.2×10^{2}
	50	1.6×10^{2}	2.1×10^{2}
	100	1.4×10^{1}	1.5×10^{1}
	200	8.8×10^{1}	5.9×10^{1}
	500	5.5×10^{1}	8.0×10^{1}
	700	—	6.0×10^{1}
3	u	8.0×10^{0}	2.6×10^{1}
	20	8.0×10^{1}	2.6×10^{2}
	100	1.9×10^{2}	1.6×10^{2}
	200	1.1×10^{2}	1.1×10^{2}
	600	1.2×10^{1}	1.4×10^{1}
	1000	$>2.4 \times 10^{2}$	1.6×10^{2}
	1600	2.9×10^{1}	5.3×10^{1}
4	u	2.9×10^{1}	1.6×10^{1}
	40	2.2×10^{2}	$>4.7 \times 10^{1}$
	100	1.2×10^{1}	3.5×10^{1}
	450	2.7×10^{1}	3.5×10^{1}
	800	3.5×10^{1}	3.6×10^{1}
	1200	$>2.4 \times 10^{2}$	1.2×10^{2}
5	u	1.4×10^{2}	1.8×10^{2}
	310	$>2.4 \times 10^{2}$	$>2.4 \times 10^{2}$
8	u	$>2.4 \times 10^{2}$	$>2.4 \times 10^{2}$
	20	—	—
	20	$>1.4 \times 10^{3}$	$>1.4 \times 10^{3}$
	75	2.3×10^{3}	7.4×10^{2}
	75	8.5×10^{2}	4.0×10^{2}
	75	$>4.7 \times 10^{2}$	2.8×10^{2}
	390	4.2×10^{2}	1.8×10^{2}
	390	6.7×10^{2}	4.4×10^{2}
	390	$>4.7 \times 10^{2}$	$>4.7 \times 10^{2}$
9	u	$>1.4 \times 10^{3}$	8.8×10^{2}
	u	$>4.7 \times 10^{2}$	$>4.7 \times 10^{2}$
	825	5.7×10^{2}	5.7×10^{2}
	825	$>4.7 \times 10^{2}$	$>4.7 \times 10^{2}$
	825	$>2.4 \times 10^{2}$	$>2.4 \times 10^{2}$
10	500	4.2×10^{2}	$<3.5 \times 10^{1}$
	500	9.9×10^{2}	8.8×10^{2}
	500	2.9×10^{2}	4.7×10^{2}
	1500	7.8×10^{2}	1.3×10^{2}
	1500	$>4.7 \times 10^{2}$	—
	1600	2.8×10^{2}	1.4×10^{2}
	1600	3.5×10^{2}	1.1×10^{2}
	1600	1.3×10^{2}	9.4×10^{1}
11	1	1.4×10^{2}	$<7.1 \times 10^{1}$
	1	7.4×10^{2}	2.8×10^{2}
	1	3.6×10^{2}	1.8×10^{2}
	1	2.8×10^{1}	4.2×10^{1}
	1600	4.5×10^{2}	2.1×10^{2}
	1600	$>4.7 \times 10^{2}$	$>4.7 \times 10^{2}$

mean of 42.1 percent. As can be seen, the far downwind results resembled the size distribution of the background samples for percent respirable, while the close downwind samples collected a higher percentage of respirable (small) particles.

For total coliform, the background was represented by two upwind samples and ten samples taken more than 100 meters from the spray line. The distances of these samples ranged from 390 to 1600 meters. Percentage of the total particles in the respirable range for the background ranged from 29 percent to 92 percent, with a median of 48 percent and a mean of 53.8 percent. The samples taken close to the spray line were at distances of 20, 75 and 100 meters and no further division of these values was made. The percent respirable at these distances went from a low of 29 percent to a high of 87 percent, based upon seven observations. The

Table VI.B-43.

AEROSOL PARTICLE SIZE DISTRIBUTION FROM TWO-STAGE ANDERSON SAMPLERS —TOTAL COLIFORM (Percent)

Run	Distance ,m	Stage I (Non-Respirable)	Stage II (Respirable)
7	100	26	74
	100	36	64
8	u	—	—
	20	19	81
	20	17	83
	75	13	87
	75	33	67
	75	71	29
	390	—	—
	390	60	40
	390	48	52
9	u	50	50
	u	58	42
	825	71	29
	825	54	46
	825	65	35
10	500	—	—
	500	71	29
	500	—	—
	1500	30	70
	1500	—	—
	1600	—	—
	1600	25	75
	1600	8	92
11	1	—	—
	1	38	62
	1	30	70
	1	—	—
	1600	—	—
	1600	29	71

Table VI.B-44.
AEROSOL PARTICLE SIZE DISTRIBUTION FROM TWO-STAGE ANDERSEN SAMPLERS—TOTAL COUNT
(Percent)

Run	Distance, m	Stage I (Non-Respirable)	Stage II (Respirable)
1	u	76	24
	5	30	70
	25	30	70
	50	74	26
	100	80	20
	150	—	—
2	u	78	22
	10	35	65
	50	43	57
	100	48	52
	200	60	40
	500	41	59
	700	—	—
3	u	24	76
	20	24	76
	100	54	46
	200	50	50
	600	46	54
	1000	—	—
	1600	35	65
4	u	64	36
	40	—	—
	100	26	74
	450	44	56
	800	49	51
	1200	—	—
5	u	44	56
	310	—	—
8	u	—	—
	20	—	—
	20	—	—
	75	76	24
	75	68	32
	75	—	—
	390	70	30
	390	60	40
	390	—	—
9	u	—	—
	u	—	—
	825	50	50
	825	—	—
	825	—	—
10	500	—	—
	500	53	47
	500	38	62
	1500	86	14
	1500	—	—
	1600	67	33
	1600	76	24
	1600	58	42
11	1	—	—
	1	72	28
	1	67	33
	1	46	60
	1600	68	32
	1600	—	—

median percent respirable was 74 percent, with a mean of 72.7 percent. In general, then, there was a higher percentage of respirable total coliforms close to the spray line.

The results can be compared to other studies conducted at Ft. Huachuca, Arizona, and at Chicago, Illinois. In each of these studies, the six-stage Andersen sampler was used, but the division according to respirable (Stage 1) and nonrespirable (Stages 2-6) particles can be made. In the Ft. Huachuca study, the respirable portion of the total viable particles accounted for 70-80 percent of the total particles for three of the four runs. On the fourth run, only 50-60 percent of the particles were in the respirable range. These are similar to the data obtained in this study.

At the Chicago site both standard bacterial plate count and total coliform data were obtained. For standard bacterial plate count, the upwind sample gave a respirable portion of 35 percent, slightly below the median for this study. The results showed median values of 67 percent for close downwind (10-20 meters) and 55 percent respirable for farther downwind (100 meters), similar to those for this study. No samples were obtained beyond 200 meters in that study.

For total coliform, only at one distance were nonrespirable particles isolated at 97 meters downwind. However, the actual counts obtained at all distances fell below the recommended minimum of 30 particles and these data provide little comparative utility.

6. Aerosol Microbial Characterization

A special aerosol run, M1-36, was made with eight samplers set side-by-side at 20 meters from the wet-line edge to collect a high-volume aerosol sample for pathogen screen. Run M1-36 was conducted on the dry side of Field 3-1 at night (2137-2207) on June 21, 1976, at a temperature of 12°C, a relative humidity of 82 percent, and a wind velocity of 1.6 m/s. The BHI sample collection fluid from all samplers was aggregated and analyzed both by the qualitative pathogen screen procedure used for the high-volume wastewater samples and by the usual quantitative procedure. The aerosol microbial characterization results are presented as Run 36 in Tables VI.A-19 and VI.A-21 for comparison with the wastewater microbial characterization. The aerosol concentrations obtained from this sample are given in Table VI.B-45. The mycobacteria aerosol concentration was surprisingly high on this run. The prevalence of mycobacteria in this aerosol sample and in the wastewater microbial characterization sample during Pre-Fair was the basis for its selection as a microorganism group to be routinely monitored in the Post-Fair sampling. In addition to the microorganism groups listed in Table VI.B-45, the pathogen screen identified *Proteus*, *Enterobacter*, "other oxidase-negative gram-negative nonfermenters," and "other oxidase positive fermenters." While the aerosol bacteria identified were representative of those found in the wastewater microbial characterizations, fewer bacterial types were found in the aerosol, as expected.

Table VI.B-45.
AEROSOL CONCENTRATIONS FOR THE AEROSOL MICROBIAL CHARACTERIZATION RUN

MICROORGANISM GROUP	AEROSOL CONCENTRATION
Std. Bacterial Plate Count	7800 /m^3
Total Coliform	43 MFC/m^3
Fecal Coliform	6.0 MFC/m^3
Fecal Streptococci	2.3 CFU/m^3
Pseudomonas	240 CFU/m^3
Mycobacteria	280 CFU/m^3
Klebsiella	4.1 CFU/m^3
Clostridium perfringens	4.3 MPN/m^3
Staphylococcus aureus	9 CFU/m^3

C. Aerosol Data Analyses

1. Microbiological Dispersion Model

This section presents a microbiological dispersion model that may be applicable for prediction of the viable aerosol concentration of any measureable microorganism group emanating from any sprayed wastewater aerosol source. This microbiological dispersion model incorporates the microbiological aerosol characteristics derived from the extensive aerosol sampling program of this study. Considering the imprecision and cost of measuring microorganism aerosol concentrations from spray irrigation by field sampling, using predictions of the microbiological dispersion model supplemented with minimal field sampling does appear to be a preferable alternative to extensive field sampling when the sprayed wastewater does not contain residual chlorine.

The microbiological dispersion model extends the standard air pollutant dispersion models(35), and predecessor microbiological models(36,37,38,39,40) by incorporating a site-specific parameter for aerosolization efficiency and microorganism-specific parameters for microbiological die-off.

a. *Model Derivation*

Consider the aerosol concentration, $C_g(r,d)$, of a microorganism group or dye, g, sampled under the environmental conditions of aerosol run r at a perpendicular distance d downwind from the wet-line edge of the spray line. This sampled aerosol concentration should equal the sum of the predicted microorganism concentration, $P_g(r,d)$, emanating from the spray line to that distance on the run, the existing background concentration, $B_g(r)$, of the microorganism under the run conditions, and a random error, ε_g, with a mean of zero to express the uncertainty of the relationship:

$$C = P + B + \varepsilon \qquad (1)$$

where: d = perpendicular distance from the spray wet-line edge, (m)
g = measured microorganism group or dye
r = environmental conditions during the aerosol run
C = C_g (r,d) = sampled aerosol concentration of microorganism g at distance d during run r, (cfu/m^3, colony forming units per cubic meter)
B = B_g (r) = sampled background aerosol concentration of microorganism g during run r (upwind of the spray line), (cfu/m^3)
P = P_g (r,d) = predicted aerosol concentration of microorganism g emanating from the spray line to a distance d during run r obtained using the microbiological dispersion model, (cfu/m^3)
ϵ = ϵ_g = random error with zero mean representing the measurement errors in C and B and the prediction error in P, (cfu/m^3).

The variance of ϵ is the sum of the variances of C, B, and P under the reasonable assumption of independence. The measured concentrations C and B have a relatively constant coefficient of variation, α_g, which was estimated in Section VI. B.4.b. as the measurement variation for each microorganism, g. Thus, the variance of ϵ is:

$$\mathrm{Var}(\epsilon_g) = \alpha_g^2(C_g^2 + B_g^2) + \mathrm{Var}(P_g)$$

Since α_g ranges from 0.50 for total coliform and standard bacterial plate count to 0.81 for mycobacteria, and since aerosol model predictions may be expected to have coefficients of variation in the same range, the standard deviation of ϵg probably ranges between 70 and 110 percent of the aerosol concentration, C. Thus, equation (1) contains a substantial degree of uncertainty.

Figure VI.C-1 depicts the transport of aerosol downwind of a spray line to a position, x. Let:

a = a(r,d) = aerosol age at distance d during run r, (s)
u = mean wind velocity during run r, (m/s)
w = wet-line edge distance during run r, (m)
ϕ = angle of the wind direction with the perpendicular to the line of the spray heads.

Then the aerosol age, a, is computed as

$$a = \frac{w + d}{u \cos \phi} \tag{2}$$

At d = 50m, for example, $a_{50} = (w + 50m)/(u \cos \phi)$.

The following multiplication model for the predicted concentration, P, coming from the spray line is postulated:

$$P = D \times E \times I \times e^{\lambda a} \tag{3}$$

where the model parameters are:

D = D_g (r,d) = physical diffusion model aerosol concentration of microorganism g emanating from the spray line to a distance d during run r, assuming all the sprayed wastewater (including its measured wastewater concentration of microorganism g) becomes aerosol, and assuming no microbiological die-off, (cfu/m^3)
E = E(r) = aerosolization efficiency factor: the fraction of the sprayed wastewater that is aerosolized during run r, ($0 < E \leq 1$)

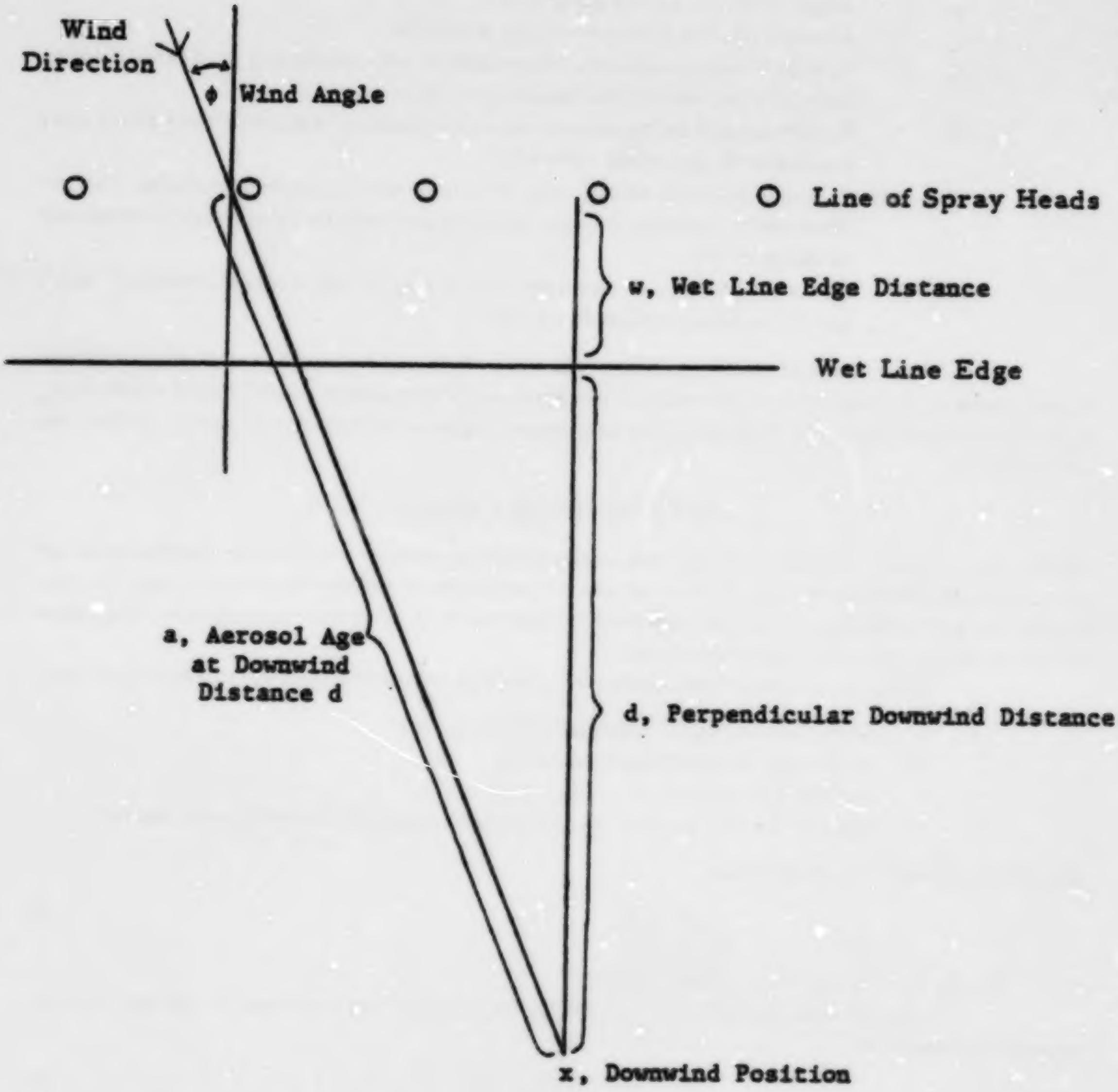

Wind Direction
ϕ Wind Angle
Line of Spray Heads
w, Wet Line Edge Distance
Wet Line Edge
a, Aerosol Age at Downwind Distance d
d, Perpendicular Downwind Distance
x, Downwind Position

Figure VI.C-1.
SCHEMATIC OF AEROSOL TRANSPORT DOWNWIND OF A SPRAY LINE

I = $I_g(r)$ = microbiological impact factor: the proportion of the aerosolized microorganisms of group g that remain viable immediately after aerosolization during run r, $(I>0)$

λ = $\lambda_g(r)$ = microbiological age decay rate: rate at which the microorganisms of group g die off with aerosol age during run r, $(\lambda\leq 0)$.

The exponential microbiological viability decay factor, $e^{\lambda a}$, expresses the reasonable assumption that the run, r, environmental conditions kill a constant proportion, λ, of the remaining number of the viable microorganisms of group g in the aerosol cloud with unit increase in the aerosol age, a.

Dispersion models generally(41, 42) contain a source strength term Q, in units of mass per unit time, to express the pollutant emission rate at the source. For spray irrigation, Q is calculated as the product of four factors: the wastewater concentration of the microorganism, the wastewater application rate, the aerosolization efficiency (E), and the impact factor (I) for the microorganism. In the microbiological dispersion model, the wastewater concentration and application rate factors are included in D, while E and I are specified separately. This permits separate estimation of the E and I factors.

b. Effect of Each Model Factor

The effect of each factor of the microbiological dispersion model, P, is depicted schematically in Figure VI. C-2. The physical diffusion model calculates a very high microbiological aerosol concentration, D, because it assumes that all of the sprayed wastewater is converted to aerosol and that all of the microorganisms measured in the wastewater remain viable while entering and being transported in the aerosolized state.

Actually, only a small fraction, E, of the sprayed wastewater becomes aerosolized. The aerosolization efficiency factor, E, depends upon the type of spray equipment employed, the spray head pressure, and such meteorological conditions, r, as the ambient wind velocity and air temperature. Typical values of E are in the range of 0.001 to 0.01 (i.e., 0.1% to 1% of the sprayed wastewater). Thus, when the amount of wastewater actually aerosolized is taken into account, a much lower microbiological aerosol concentration, $D \times E$, is obtained.

Further impact changes, I, in microbiological aerosol concentration occur during entry into the aerosolized state. Originally it was assumed that these impact changes were reductions, varying in magnitude for different microorganism groups, g, and environmental conditions, r, that would result from the shock of entry into the inhospitable aerosol environment and from possible collection inefficiency in the aerosol samplers. However, the estimates of I to be presented later consistently exceed 1.0 for the hardy microorganisms (i.e., those microorganisms that survive best in the aerosol environment). As will be discussed later, the impact factor, I, is actually an empirical catchall for various microorganism-specific initial effects. With the impact factor contribution, the resulting aerosol concentration at the spray line is $D \times E \times I$.

Finally, there is gradual exponential die-off of microorganisms after aerosolization, $e^{\lambda a}$, which is presumed to occur at a constant decay rate, λ, with aerosol age. This microbiological die-off accumulates as a result of continued exposure to hostile environmental factors, such as solar radiation and low relative humidity, throughout the travel of the aerosol cloud. Taking this exponential die-off factor into account, the aerosol concentration curve for the complete predicted concentration, $P = D \times E \times I \times e^{\lambda a}$, is obtained. Adding the background concentration, B, to the predicted concentration, P, yields the sampled aerosol concentration, $C = P + B$.

The microbiological dispersion model equations (1) and (3) were used to estimate values of the model parameters, D, E, I, and λ for each appropriate microorganism group from the aerosol sampling

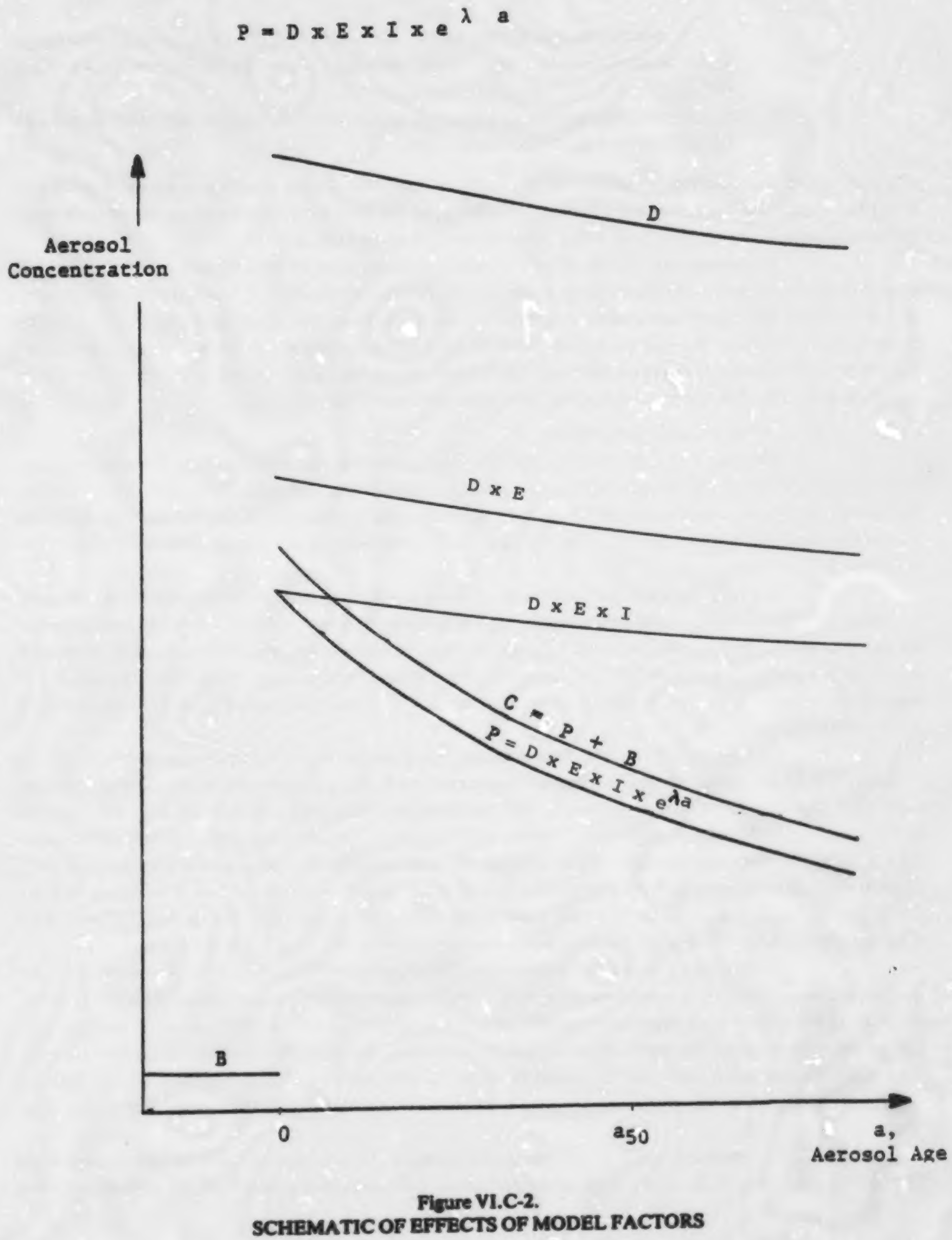


Figure VI.C-2.
SCHEMATIC OF EFFECTS OF MODEL FACTORS

program. The estimation procedures used and the model parameter estimates obtained are presented in the following three sections.

2. Diffusion Model Concentration D

The H. E. Cramer Company participated in the research effort and calculated the physical diffusion model terms, D, for each microorganism group at each sampler location during each run[43, 44] using their Volume-Source Diffusion Models Program. D is calculated using the total volume of sprayed wastewater and the measured wastewater concentration of each microorganism. Each sprayer along the sprayer line was modeled individually as a separate source. The diffused concentration contributions from each sprayer that reached a given location were then summed to compute D for that location.

a. *Approach*

Specific objectives of the H.E. Cramer Company work included:

- Calculations of the model concentrations, D, and the aerosolization efficiency, E, of the wastewater spray system for the Rhodamine WT dye tracer at each sampler during each dye aerosol run.
- Calculations of model concentrations, D, for each microorganism group sampled at each sampler during each microbiological, quality assurance, and special enterovirus aerosol run.
- Calculations of normalized concentration isopleth patterns downwind from the spray lines for each of the runs.

The concentrations, D, were calculated by means of a diffusion model under the assumptions that all of the material is aerosolized and that no material is lost by decay, gravitational deposition or other depletion processes. (i.e., all aerosol particles are small enough to be treated as a gas having no settling velocity over the aerosol ages sampled). The model calculations were made by using the Volume-Source Diffusion Models Program developed for Dugway Proving Ground by the H.E. Cramer Company from the generalized models described by Cramer[45].

A mathematical description of the Volume-Source Diffusion Models Program is presented in Appendix A of the H.E. Cramer Company technical reports[46, 47]. In the model calculations, each spray head was treated as an individual source and the model was used to calculate the composite concentration pattern produced by the discharges from all spray heads in use during each aerosol run. Meteorological inputs used in the diffusion model calculations were presented in Table VI. B-1 of this report.

b. *Source Inputs*

The source geometry of the spray lines and the positions of the active spray lines relative to the samplers were based on field measurements and observations. The spray heads were spaced about 9.1 meters apart and were about 0.6 meters above the ground. The top of the wastewater spray cone from each head was observed to be about 5 meters above the ground and the radius of the spray circle produced by each head was about 9 meters.

Volume sources with the above dimensions and spacing were used to simulate the spray lines in the model. The height and radius of the spray cone were divided by 2.15 to obtain the initial source dimensions, σ_{zR} = 2.0 meters and σ_{yR} = 4.2 meters (the standard deviations of the vertical and the lateral aerosol distributions at the source). The source height H was assumed to be 0.6 meters above ground. The distance from the projected virtual point source over which rectilinear expansion was assumed was $X_{ry} = X_{rz} = 50$ meters. The separation distance between model volume sources was set equal to 9.1 meters, and the coordinates of the spray lines and downwind sampling locations were entered on the model calculation grid.

Estimates of the source strengths (emission rates) of the dye and various microorganism groups contained in the spray were based on measurements of their wastewater concentrations during the run. To obtain emission rates for individual spray heads, these concentrations were multiplied by a flow rate. Flow-rate measurements were made for each spray head on the line directly upwind from the aerosol samplers at least once each time the spray line was moved to a new spray field. During some of the microbiological and virus aerosol runs, spray lines in other fields were operating and could have contributed to the measured concentrations at one or more of the samplers. Since flow-rate measurements were not made on these lines, the flow-rate data for those lines on other runs in the Post-Fair and Pre-Fair programs were used to estimate the flow rates for use in the model calculations.

The flow rate profiles used in the source strength calculations for the dye, microbiological and virus runs are given in Appendix C of the Cramer Pre-Fair report(48) and Appendices B, C, and D of the Cramer Post-Fair Reports(49).

c. *Calculation Procedure and Model Concentrations*

The Volume Source Diffusion Model was used with the meteorological, FP rotorod, and source inputs to produce concentration isopleth patterns for each trial. Concentrations were calculated for an array of grid points located at distances up to 1000 meters downwind from the main spray line. As noted above, grid points corresponding to the locations of the aerosol samplers were included in the array. Computer plots of the calculated concentration isopleths for the dye and microbiological trial runs are presented in Appendix B of the Cramer Pre-Fair report and in Appendices F and G of the Cramer Post-Fair report.

In this report, Figure VI. C-3 illustrates the dye concentration isopleths, D, obtained from the diffusion model for a typical dye aerosol run. The normalized isopleths calculated from the diffusion model are presented in Figures VI. C-4 and VI. C-5 for two of the microbiological aerosol runs. When these normalized isopleths are multiplied by the wastewater concentration of a microorganism group, the diffusion model microorganism aerosol concentration D is obtained.

Diffusion model concentrations, D, are presented and compared with the sampled concentrations C for each sampler on each run for each microorganism group in Appendix D of the Cramer Pre-Fair report and in Appendix E of the Cramer Post-Fair report. While the results varied considerably between runs, the diffusion model concentration D at 100 meters generally was from 50 to 80 percent of the model concentration D at 50 meters.

The model calculation procedure for the two special virus runs was modified slightly to conform to the enterovirus concentration, which was based on pooling the sample from all samplers over four and six successive 30-minute run sub-periods. The measured aerosol concentrations for the virus runs given in Table VI. B-24 thus represent an average over the sub-periods as well as over the 13 sampling locations. A similar averaging scheme was used to calculate the model concentrations. First, a set of normalized concentrations was calculated for each sub-period using model inputs derived from meteorological measurements made during the 30-minute sampling periods. The calculated concentrations for all samplers in all sub-trials were then averaged to obtain an average normalized concentration for the virus trial. Average aerosol concentrations for the enteroviruses and other microorganism groups were then obtained by multiplying the normalized concentration by their corresponding wastewater sample concentrations.

3. Aerosolization Efficiency Factor E

a. *Dye Run Aerosolization Efficiency Estimates*

An aerosolization efficiency estimate was computed for each dye aerosol run. Since the dye is not present in the background, and since it does not degrade significantly over the aerosol ages sampled, $B = 0$, $I = 1$, and $\lambda = 0$ for the dye runs. Thus, the aerosolization efficiency estimate at a dye run sampler location derived from the model equations (1) and (3) is:

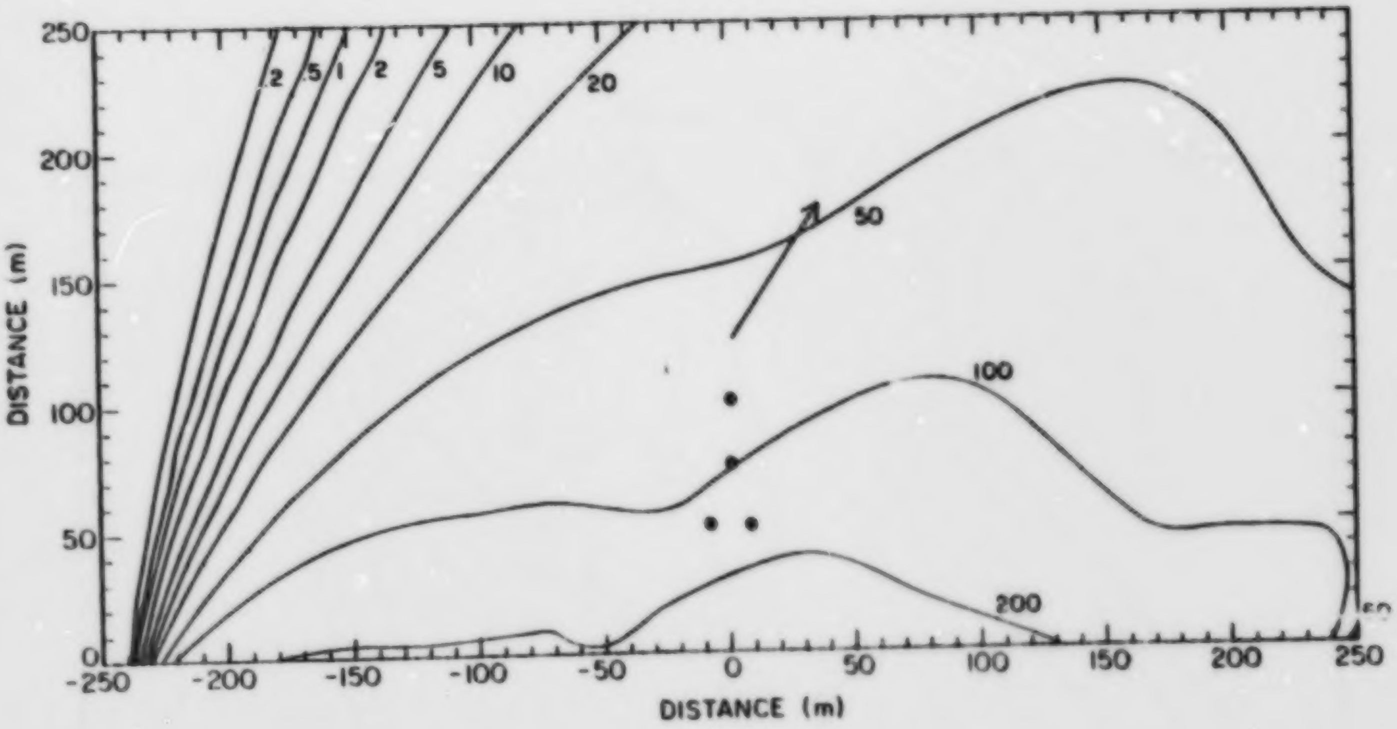


Figure VI.C-3.
CONCENTRATION ISOPLETHS OF DIFFUSION MODEL D FOR A TYPICAL DYE RUN

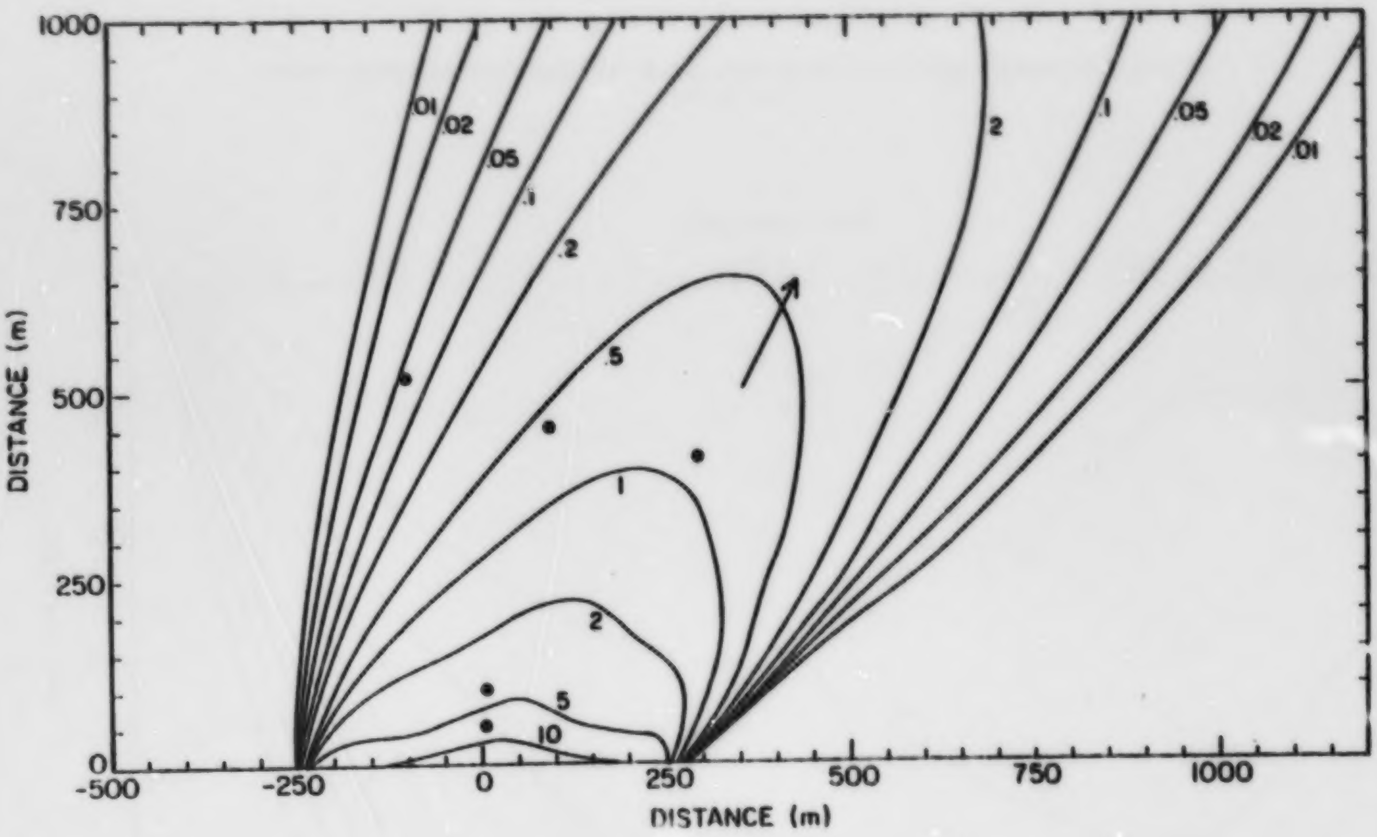


Figure VI.C-4.
NORMALIZED ISOPLETHS OF DIFFUSION MODEL D FOR A TYPICAL MICROBIOLOGICAL AEROSOL RUN

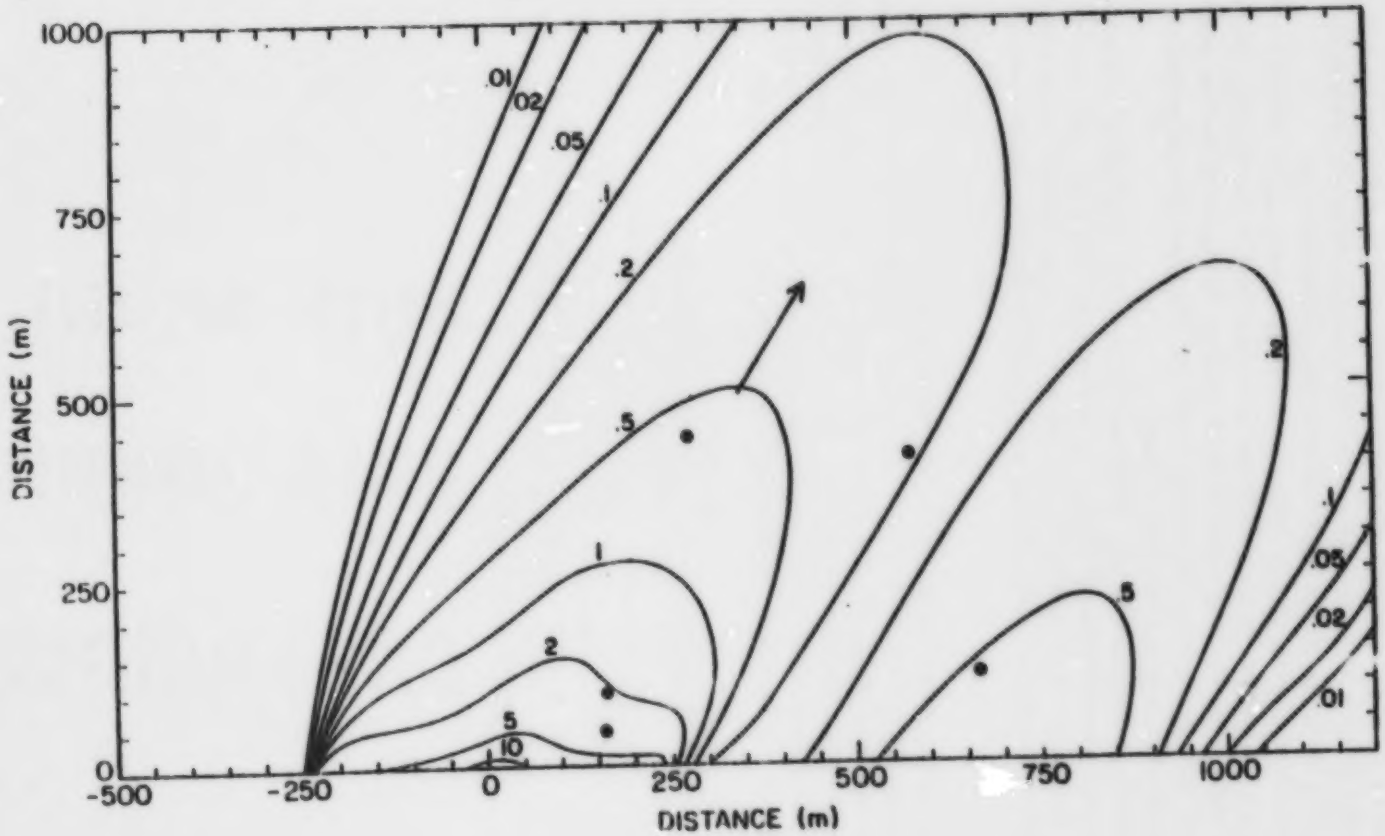


Figure VI.D-5.
NORMALIZED ISOPLETHS OF DIFFUSION MODEL D FOR A MICROBIOLOGICAL AEROSOL RUN HAVING TWO SPRAY LINE CONTRIBUTIONS

$$E = C/D \tag{4}$$

The H.E. Cramer Company computed aerosolization efficiency E values for each sampler on each dye run using equation (4). These sampler values are presented in Table D-1 of Appendix D of the Cramer Pre-Fair report and in Table E-1 of Appendix E of the Cramer Post-Fair report.

The geometric mean of the E values obtained at each sampler location beyond d = 5 meters from the wet-line edge was taken as the aerosolization efficiency estimate E for the dye run. These dye run estimates are presented in Table VI. C-1. Note that the aerosolization efficiency on the Pre-Fair dye runs conducted in late spring (May and June) were more variable and generally higher than the aerosolization efficiency for the Post-Fair dye runs during December and January.

The distribution of the 17 dye run estimates of aerosolization efficiency is summarized in Table VI. C-2. The median aerosolization efficiency value obtained at Pleasanton was 0.0033 (0.33%). There was over an order of magnitude of variation in E values from the tenth percentile (0.09% to the ninetieth percentile (1.8%). Thus, the fraction of wastewater that was aerosolized varied considerably from one run to another.

b. Microbiological Run Aerosolization Efficiency Predictions

To separate the effects of E and I during the microbiological aerosol runs conducted at Pleasanton, it was necessary to estimate E independent of the microbiological aerosol data. Thus, a regression equation was sought from the 17 dye runs to relate the E values occurring at Pleasanton to potentially relevant meteorological and operating conditions. The conditions considered were wind velocity, air temperature, relative humidity, solar radiation, wastewater temperature, spray head pressure, and seasonal bias.

Table VI.C-1.
ESTIMATES AND PREDICTIONS OF DYE RUN AEROSOLIZATION EFFICIENCY E

Dye Aerosol Runs		
Aerosol Run Number	Aerosolization Efficiency E	
	Dye Run Estimate	Regression Prediction
D1-1	.0272	.0172
D1-3	.0067	.0072
D1-4	.0019	.0022
D1-5	.0038	.0021
D1-6	.0067	.0040
D1-9	.0160	.0110
D1-10	.0059	.0168
D2-1	.0041	.0030
D2-2	.0062	.0047
D2-4	.0033	.0031
D2-5	.0023	.0023
D2-6	.0022	.0035
D2-7	.0021	.0027
D2-8	.0025	.0026
D2-9	.0014	.0013
D2-10	.0009	.0012
D2-11	.0008	.0011

Table VI.C-2.
DISTRIBUTION OF AEROSOLIZATION EFFICIENCY VALUES E

	Number of Values (Dye Runs)	Distribution of Values -- Percentiles				
				(Median)		
		10%	25%	50%	75%	90%
E, Aerosolization Efficiency at Pleasanton	17	0.0009	0.0019	0.0033	0.0064	0.018

The potential regressor variables considered for inclusion in the aerosolization efficiency regression were:

UM — wind velocity at meteorological tower, 4 meter level
US — wind velocity in spray field, 3 meter level
P — spray head pressure, Pascals
PERIOD — 1 = Pre-Fair, 2 = Post-Fair
TM — air temperature at meteorological tower, 2 meter level
TP — air temperature at effluent ponds, 2 meter height
RHM — relative humidity at meteorological tower, 2 meter level
RHU — relative humidity upwind, 2 meter height
RHL — relative humidity at Lawrence Laboratory in Livermore
WT — wastewater temperature at end of spray line, °C
R — solar radiation at meteorological tower, W/m^2
UMSQ — UM squared
USSQ — US squared
TMSQ — TM squared
TPSQ — TP squared
RSQ — R squared
RHMSQ — RHM squared
TMXRHM — product of TM and RHM
UMXP — product of UM and P
UMXTM — product of UM and TM
UMXR — product of UM and R

Most of these variables are environmental conditions whose values were given in Table VI.B-1. The average spray head pressure variable was calculated from Darcy's formula using the flow rate that was measured at the spray line for each run. Since the orifice diameters were the same for all spray heads, the expression for spray head pressure reduced to:

$$P = 21.028 \times (\text{Avg Spray Head Flow Rate})^2 \text{ Pascals}$$

where the flow rate is in liters per minute. PERIOD is a dummy variable to take into account any unmeasured systematic factors that differed between the late spring Pre-Fair dye runs and wintertime Post-Fair dye runs.

The dependent variable $\log_{10}E$ was utilized. Inspection of the dye run E values in Table VI.C-1 suggests the uncertainty in an E estimate may be proportional to the estimated value. Thus, regression on $\log_{10}E$ should yield a relatively constant error term.

Stepwise regression yielded numerous candidate regression equations involving a similar set of regressor variables, many of which were highly correlated with each other. Because its regressor variables were less correlated, the following regression equation was selected to predict the aerosolization efficiency E at Pleasanton over the wide range of meteorological conditions encountered:

$$\log_{10}E = 0.031\, t + 0.000096\, u{*}r - 3.10 \qquad (5)$$

where t = air temperature, °C
u = wind velocity, m/s
r = solar radiation, W/m^2

With a coefficient of multiple determination $R^2 = 0.801$, this regression explains 80 percent of the observed variation in $\log_{10}E$. The standard error SE = .194 implies that the true aerosolization efficiency E will be between $0.64\,\hat{E}$ and $1.56\,\hat{E}$ of the equation (5) estimate $\hat{E}$ for about two-thirds of the estimates.

Predicted values of aerosolization efficiency obtained using regression equation (5) are also provided in Table VI.C-1 for each dye run. The Pleasanton aerosolization efficiency predicted by regression was usually within a factor of two of the dye run estimates.

Using equation (5), predictions of the aerosolization efficiency were also made for each microbiological aerosol run. These predictions are presented in Table VI.C-3.

4. Impact Factor I and Aerosol Viability Decay Rate λ

a. *Estimation Procedures for I and λ*

(1) Standard Estimation Procedure

The values of I and λ for a microorganism group during a run were estimated jointly by simple linear regression using the aerosol concentrations obtained from each of the samplers. Substituting the equation (1) expression for P into equation (3), rearranging terms, and taking natural logarithms, one obtains

$$\ln\left(\frac{C_d - B}{D_d \cdot E}\right) = \ln I + \lambda a_d \tag{6}$$

This equation has the form of a simple linear regression model

$$y_d = b_o + b_1 a_d + \varepsilon_d \tag{7}$$

where values of the dependent variable, $y_d = \ln[(C_d - B)/(D_d \cdot E)]$, and of the independent variable, a_d = aerosol age, can be computed as an observation pair (y_d, a_d) for each downwind sampler at distance, d, that obtained a detectable microorganism concentration, C_d, above the background level, B. Since $b_0 = \ln I$ and $b_1 = \lambda$, the estimates of I and λ are readily calculated from the coefficient estimates for b_0 and b_1 resulting from the simple linear regression on the n observation pairs for the microorganism and run:

$$\begin{aligned} \hat{I} &= \exp(\hat{b}_o) \\ \hat{\lambda} &= \hat{b}_1 \end{aligned} \tag{8}$$

where $$\hat{b}_1 = \frac{\Sigma a_d y_d - \Sigma y_d \Sigma a_d / n}{\Sigma a_d^2 - (\Sigma a_d)^2 / n} \qquad \hat{b}_o = \bar{y} - \hat{b}_1 \bar{a}$$

The uncertainty in the equation (8) estimates of I and λ for a microorganism group on a run can be estimated from the deviation of the y_d values about the linear regression equation (7) estimates $\hat{y}_d$. Using the expressions for the standard errors of the regression coefficients(50) s.e($\hat{b}_0$) and s.e($\hat{b}_1$), and the usual variance functional transformation(51),

$$\mathrm{Var}(y) \approx \left(\frac{dy}{dx}\right)^2_{x = E(x)} \cdot \mathrm{Var}(x)$$

the standard errors of the estimators $\hat{l}$ and $\hat{\lambda}$ are

$$s.e.(\hat{l}) \approx \hat{l}\, s.e.(\hat{b}_o) = \hat{l}\sqrt{\frac{\Sigma a_d{}^2}{n\Sigma(a_d - \bar{a})^2}}\sqrt{\frac{\Sigma(y_d - \hat{y}_d)^2}{n-2}} \qquad (9)$$

$$s.e.(\hat{\lambda}) = s.e.(\hat{b}_1) = \frac{1}{\sqrt{\Sigma(a_d - \bar{a})^2}}\ \sqrt{\frac{\Sigma(y_d - \hat{y}_d)^2}{n-2}}$$

The standard estimation procedure was to jointly estimate l, λ, and their standard errors for each microorganism group on each run using equations (8) and (9). This procedure was applied if

Table VI.C-3.
REGRESSION PREDICTION OF AEROSOLIZATION EFFICIENCY E FOR THE MICROBIOLOGICAL AEROSOL RUNS

Microbiological Aerosol Runs			
Aerosol Run Number	Regression Prediction E	Aerosol Run Number	Regression Prediction E
M1-1	.0072	M2-1	.0018
M1-2	.0057	M2-2	.0021
M1-3	.0039	M2-3	.0012
M1-4	.021	M2-4	.0017
M1-5	.0091	M2-5	.0015
M1-6	.0024	M2-6	.0023
M1-7	.0016	M2-8-9	.0027
M1-8	.0067	M2-10	.0015
M1-9	.0058	M2-11	.0034
M1-10	.0019	M2-12	.0030
M1-11	.0024	M2-13	.0012
M1-12	.0041	M2-14	.0018
M1-13	.0017	M2-15	.0028
M1-14	.0016	M2-16	.0024
M1-15	.0016	M2-17	.0025
M1-16-19	.0016	M2-18-21	.0019
M1-20-23	.0035	M2-22	.0066
M1-24-25	.0018	M2-23	.0065
M1-26	.0018	M2-24	.0050
M1-27-30	.0096	M2-25	.0092
M1-31	.0060	M2-26	.0054
M1-32	.024	M2-27-28	.0058
M1-33	.021	M2-29	.0074
M1-34	.0036	M2-30	.0085
M1-35	.0024	M2-31	.0015
		M2-32	.0021
		M2-33	.0074
		M2-34	.0025
		M2-35	.0132
		M2-36	.0068
		M2-37	.0079
		M2-38	.0050
		V2-I	.0028
		V2-II	.0045

there were more than n = 2 valid observation pairs for the microorganism group at two or more distances on the aerosol run, if the viability decay rate estimate from equation (8) was negative ($\hat{\lambda} < 0$), and if each of the observation pairs were considered to have roughly equivalent weight.

(2) Special Estimation Procedures

For the hardier microorganism groups, joint estimation of I and λ by equations (8) often yielded a positive value for the viability decay rate λ. A positive λ implies growth rather than die-off of the microorganism with lengthening exposure to the hostile aerosol environment. Significant net growth in aerosols over durations up to several minutes is highly unlikely. Thus, positive λ values probably result from the substantial uncertainty error in the model equations (1) and (3) in those situations when the actual decay rate was too slight to be detected. This uncertainty error is attributable to measurement variation, localized microbial aerosol sources, and estimation errors in D and E. Accordingly, positive λ values obtained by equations (8) were considered indistinguishable from λ = 0 and denoted as λ = X

Substituting λ = 0 in equation (6) yields a distinct value $I_d = (C_d - B)/(D_d \bullet E)$ for each downwind sampler. The geometric mean of these downwind sampler values was taken as the impact factor I estimate when the λ estimate was considered indistinguishable from zero:

$$\hat{\lambda} = X$$

$$\hat{I} = \underset{\text{over all d}}{\text{Geometric Mean}} (I_d) = \exp(\overline{y}) \tag{10}$$

Assuming λ = 0 were known, the standard error of the equation (10) $\hat{I}$ is s.e.$(\hat{I}) = \hat{I}\, s/\sqrt{n}$ where $s^2 = \Sigma(y_d - \overline{y})^2/(n - 1)$. Because λ is actually indeterminate in such cases, the $\hat{I}$ standard error is probably larger than this, and may be better reflected by the equation (9) estimator. Thus, when joint estimation by equations (8) yield a positive λ estimate, equations (10) were used to estimate I and λ and the standard error of $\hat{I}$ was estimated as

$$\text{s.e.}(\hat{I}) = \text{Max}\,[\hat{I} s\sqrt{n}, \hat{I}\,\text{s.e.}(b_o)] \tag{11}$$

When there were only n = 2 observation pairs per run, and when the observation pairs did not have roughly equivalent weight, variants of the standard joint estimation procedure [equations (8) and (9)] and the indeterminate decay rate estimation procedure [equations (10) and (11)] were used. For n = 2, equation (6) represents n = 2 equations in two unknowns (I and λ). $\hat{I}$ and $\hat{\lambda}$ were estimated as the exact solution of these simultaneous equations. When $\hat{\lambda}$ was positive, equations (10) and (11) with n = 2 were used for the estimation.

Because the sampling designs used spread the samplers farther apart at the greater distances, d, the observation at the most distant of the designated downwind samplers usually had the greatest effect on the estimated viability decay rate, λ. However, the concentration, C_d, at this sampler was occasionally below the detection limit and, thus, arbitrarily close to the background concentration, B. On such a regression, the most distant observation y value had considerably greater uncertainty than did the others and should hence receive less weight. In these cases, a weighted regression estimation procedure was used(32). The weighted simple linear regression model is

$$\sqrt{w_d}\, y_d = b_0\sqrt{w_d} + b_1\sqrt{w_d}\, a_d + \sqrt{w_d}\, \epsilon$$

where the observation, d, weight, w_d, was based on the number of CFUs (colony forming units) obtained during analysis of the aerosol sample:

CFUs Found	Raw Weight
0	0.125
1	0.5
2	0.75
3	0.9
≥4	1.0

The raw weights were standardized so that $\Sigma w_d = n$. The estimation procedure can still be represented by equations (8) and (9) when $\hat{\lambda} < 0$ and by equations (10) and (11) when the equations (8) λ were positive, provided each summation in these equations is replaced by a weighted summation [e.g., $\Sigma a_d y_d$ becomes $\Sigma w_d a_d y_d$, Σy_d becomes $\Sigma w_d y_d$, and $\Sigma(y_d - \hat{y}_d)^2$ becomes $\Sigma w_d(y_d - \hat{y}_d)^2$].

b. Impact Factor I

The estimated impact factor $\hat{I}$ and its standard error s.e. ($\hat{I}$) were obtained for each microorganism group on each aerosol run by applying the appropriate estimation procedure to the data of Tables VI.B-8 through VI.B-15. The run estimates of $\hat{I}$ and s.e.($\hat{I}$) are presented in Table VI.C-4.

Comparison of an individual impact factor estimate $\hat{I}$ against its corresponding standard error s.e.($\hat{I}$) throughout Table VI.C-4 shows there is considerable uncertainty in the individual impact factor estimates. The standard error is generally of the same order of magnitude as the impact factor estimate. Considering the sizable measurement variation in the aerosol concentrations C (cf. Section VI.B.4.b), the large

Table VI.C-4.
RUN ESTIMATES OF MICROORGANISM GROUP IMPACT FACTOR I AND STANDARD ERROR SE(I)
a. Pre-Fair Runs

Aerosol Run Number	Standard Plate Count		Total Coliform		Fecal Coliform		Coliphage		Fecal Streptococci		Pseudomonas		Clostridium Perfringens	
	Î	SE(Î)	Î	SE(Î)	Î	SE(Î)	Î	SE(Î)	Î	SE(Î)	Î	SE(Î)	Î	SE(Î)
M1-1	2.0	4.3												
M1-2	.357	.082	.046	.014	.126	.051								
M1-3	.25	.13	.048	.014	.062	.095	.0077	.0040						
M1-4			.028	.074							1.07	.78		
M1-5	.022	.010	.84	.29	.16	.16	.0006	.0012			14	14	1.22	.28
M1-6	.34	.13	.153	.056	.13	.10	1.18	.30	3.2	3.9	40	92	4.9	1.8
M1-7	.347	.054	.053	.038	.073	.015	.094	.052			210			
M1-8	.23	.28	.13	.13			.62	.33			5.1	1.2	.34	.19
M1-9	.089	.063	.040	.021	.088	.023	.134	.077	.64	.45	2.7	3.7	.237	.079
M1-10	.20	.15	.59	.20	1.19	.70	1.53	.87	2.65	.51	52	28	.62	.31
M1-11	.139	.033	1.08	.86	.54	.35	.277	.073	4.4	2.8	2.2	1.0	.064	.021
M1-12	.21	.13	.12	.12			.38	.13	21.2	5.3			7.3	4.1
M1-13	1.48	.46	.252	.042			1.42	.30	7	11	400	610	6.5	3.3
M1-14			.57	.29			1.34	.56	70	72			6.0	7.0
M1-15			.102	.023	.62	.49	.17	.10	25.8	6.9	1.14	.89	7.2	5.4
M1-31	.71	.14	.084	.066	.091	.047	.33	.53	.26	.12	1.09	.19	.736	.049
M1-32	.21	.13	.0037	.0010	.016	.018	.031	.045						
M1-33	.163	.077	.013	.012			.17	.47	.101	.028				
M1-34			1.1	1.8	.048	.035			1.9	4.1	26.3	9.5		
M1-35	.18	.12	1.06	.23	2.9	1.9	1.00	.61	6.1	1.9	94	62		

uncertainty in the impact factor estimates $\hat{I}$ is not surprising. The ratio of the estimate $\hat{I}$ to its standard error s.e.($\hat{I}$) has the t distribution with n-2 degrees of freedom, where n is the number of observation pairs regressed for the microorganism on the run. Table VI.C-5 summarizes these t statistics, $t = \hat{I}/s.e.(\hat{I})$, by microorganism group. For most microorganism groups, less than half of the impact factor estimates exceed twice their standard error. The exception is the total coliform $\hat{I}$ estimates, 62 percent of which exceed twice their standard error. Hence, the individual impact factor estimates generally have low reliability. However, the majority of $\hat{I}$ estimates (ranging from 63 percent for coliphage to 91 percent for *Clostridium perfringens*) do exceed their standard error. Thus, aggregating the individual run $\hat{I}$ estimates for a microorganism group as an I-value distribution for the microorganism group should provide a good representation of the central tendency of I for the microorganism group and a fair representation of its dispersion under different run conditions. The empirical distribution of these impact values for each microorganism is presented in Table VI.C-6.

The microorganism groups are arranged in Table VI.C-6 according to the magnitude of their median and quartile impact factor values. The microorganisms differ substantially with respect to their middle range of impact factor values. The "indicator" microorganism groups—total coliform, fecal coliform, standard bacterial plate count, and coliphage—all had a similar middle range of impact factor values. The

Table VI.C-4.
RUN ESTIMATES OF MICROORGANISM GROUP IMPACT FACTOR I AND STANDARD ERROR SE(I)
b. Post-Fair Runs

Aerosol Run Number	Standard Plate Count		Total Coliform		Coliphage		Fecal Streptococci		Mycobacteria		Enteroviruses	
	$\hat{I}$	SE($\hat{I}$)	$\hat{I}$	SE($\hat{I}$)	$\hat{I}$	SE($\hat{I}$)	$\hat{I}$	SE($\hat{I}$)	$\hat{I}$	SE($\hat{I}$)	3-Day $\hat{I}$	3 & 5 Day $\hat{I}$
M2-1	.35	.14	22.2	3.3	.163	.044	.8	2.5				
M2-2			.06	.11	1.2	1.2	.84	.61				
M2-3	.11	.11	1.05	.12	.68	.81	34	14				
M2-4			.47	.19	2.0	.36	9.4	6.2				
M2-5			.225	.044	.17	.10	.97	.10				
M2-6	.8	3.1	.573	.046			.52	.49				
M2-10			.148	.064	.34	.22						
M2-11			.143	.067	.34	.38						
M2-12	.2	1.1	.032	.090	.18	.12	1.7	2.4				
M2-13			.162	.053	.91	.16	3.0	2.4				
M2-14			1.97	.44	2.8	1.4	2.3	1.1				
M2-15	.102	.085	.143	.053	.45	.90	.46	.23				
M2-16	.055	.059	.184	.061	.72	.19	.71	.21				
M2-17	.25	.16	.175	.052	.35	.16	1.31	.40				
M2-22	.069	.066	.104	.071	3.6	5.1						
M2-23	.19	.10			.016	.038						
M2-24	.288	.003	.20	.34	.74	.85	.283	.088				
M2-25	.18	.13	.24	.18	.62	.51	5.5	1.9				
M2-26			.30	.13								
M2-29	.217	.072			.70	.56			2.5	8.7		
M2-30			.0110	.0054	.061	.071			.14	.11		
M2-31	.209	.072	.130	.023	.45	.82	1.0	1.2	.83	.76		
M2-32	.025	.022	.0161	.0018	12	20			1.15	.88		
M2-33					.018	.017	.12	.11				
M2-34	1.4	2.1			.071	.025			.76	.53		
M2-35	.053	.055	.0160	.0037	.0635	.0039	.73	.68	31	24		
M2-36			.32		.014	.015			.95	.51		
M2-37			.281	.154	.08	.10	1.10	.77	.81	.19		
M2-38	.88	.16	1.31	.88	.101	.027	59	26				
V2-I											44	69
V2-II											<4.7	24

inter-quartile ranges were (0.06—0.6) for total coliform, (0.07—0.6) for fecal coliform, (0.1—0.4) for standard bacterial plate count, and (0.09—0.9) for coliphage. It is important to note that all of the pathogenic bacteria and virus groups had substantially higher middle ranges of I than did these indicator microorganisms. The bacterial pathogen impact factor middle ranges extended from (0.8—2) for mycobacteria, (0.2—7) for *Clostridium perfringens*, and (0.7—6) for fecal streptococci to (2—70) *Pseudomonas*. While only two impact factor estimates were obtained for each enterovirus group, the enteroviruses appear to have a middle range at least as high as any bacterial pathogen evaluated. The five-day enteroviruses (when polioviruses were not suppressed) appear to have a middle range that is more than 100 times as high as any indicator microorganism group.

Frequent impact factor values exceeding 1.0 were not expected for any microorganism group. However, over half of the I estimates for enteroviruses, *Pseudomonas*, fecal streptococci, and *Clostridium perfringens* exceeded 1.0. Possible explanations for the consistent occurrence of pathogen I values above 1.0 are presented and discussed in Section VII.C.

The impact factor estimates I for most microorganism groups exhibited about two orders of magnitude of variation in value between their tenth and ninetieth percentiles on the Pleasanton runs. The standard bacterial plate count impact values were somewhat more consistent than those of the more specific microorganism groups.

c. *Viability Decay Rate λ*

The individual viability decay rate estimates $\hat{\lambda}$ and their standard errors s.e.($\hat{\lambda}$) calculated for

Table VI.C-5.
RELIABILITY OF IMPACT FACTOR ESTIMATES I

Microorganism Group	No. of ($\hat{I}$, s.e.($\hat{I}$)) Estimates	Percentage of Estimates Exceeding: Two Std. Errors t>2	Percentage of Estimates Exceeding: Std. Error t>1
Std. Bacterial Plate Count	33	39%	76%
Total Coliform	42	62%	86%
Fecal Coliform	13	23%	77%
Coliphage	43	30%	63%
Fecal Streptococci	31	45%	77%
Pseudomonas	12	33%	67%
Clostridium perfringens	11	45%	91%
Mycobacteria	8	13%	88%

Note: $t = \hat{I}/\text{s.e.}(\hat{I})$

Table VI.C-6.
DISTRIBUTIONS OF AEROSOL IMPACT FACTOR, I

Impact Factor, I Microorganism Group	Number of Estimates (Aerosol Runs)	Distribution of Values - Percentiles										
		5%	10%	25%		40%	50%	60%		75%	90%	95%
Fecal Coliform	13		.029	.068		.090	.13	.15		.58	2.0	
Total Coliform	44	.012	.016	.060		.13	.16	.23		.55	1.1	1.6
Std. Bacterial Plate Count	33	.021	.036	.11		.19	.21	.24		.35	1.2	1.7
Coliphage	43	.009	.017	.094		.18	.34	.52		.91	1.8	3.4
Mycobacteria	8		~.13	.77		.82	.89	1.0		2.1	~34	
Clostridium perfringens	11		.085	.24		.71	1.2	5.1		6.5	7.3	
Fecal Streptococci	31	.11	.27	.71		.97	1.7	2.7		6.1	32	64
Pseudomonas	13		1.1	1.7	(33%)	4.1	14	32	(67%)	73	320	
3-Day Enteroviruses	2				<4.7		~10		44			
5-Day Enteroviruses	2				24		~40		68			

~x – Interpolated or extrapolated value x.

each microorganism and run from the data of Tables VI.B-8 through VI. B-15 are presented in Table VI.C-7. The percentage of indeterminate viability decay rates ($\hat{\lambda}$ = X) in Table VI.C-7 is summarized in Table VI.C-8. For all microorganism groups except total and fecal coliform, indeterminate decay rates were prevalent. We interpret these indeterminate values $\hat{\lambda}$ = X as reflecting a very slight (negative) decay rate which could not be estimated because of the large uncertainties in the aerosol concentrations C and the background concentration B, relative to the limited range of sampled aerosol ages. Their prevalence suggests that many of the estimated negative decay rates may also be indistinguishable from no decay ($\lambda = 0$).

For the estimated negative decay rates, their t statistics, $t = \hat{\lambda}/s.e.(\hat{\lambda})$, are summarized by microorganism group in Table VI.C-9. Only for total coliform and fecal coliform do more than half of the negative viability decay rate estimates exceed twice their standard error. However, over 60 percent of the estimates exceed one standard error for all frequently estimated groups.

The distribution of the Table VI.C-7 viability decay rates for each microorganism group is presented in Table VI.C-10. The indeterminate viability decay rates are indicated by an X in Table VI.C-10. Question marks have been placed in parentheses after the smallest negative viability decay rates, since the prevalence of X's suggests these values may also be indistinguishable from $\lambda = 0$.

Based on their viability decay rates, the microorganism groups seem to fall into three categories. Total coliform and fecal coliform exhibit the most rapid decay and their decay rates could most frequently be estimated. Furthermore, based on their t statistics, the viability decay rate estimates for total and fecal coliform are also more reliable than for the other microorganism groups. Viability decay appeared to occur on about 50 percent of the runs for coliphage, *Clostridium perfringens* and standard bacterial plate county; their rates of decay were also slower than the coliform decay rates. Decay with aerosol age could seldom be detected for mycobacteria, *Pseudomonas*, and fecal streptococci.

For all microorganism groups, the upper portion of the λ distribution, which represents the

Table VI.C-7.

RUN ESTIMATES OF MICROORGANISM GROUP VIABILITY DECAY RATE λ AND STANDARD ERROR SE(λ), s^{-1}

a. Pre-Fair Runs

Aerosol Run Number	Standard Plate Count		Total Coliform		Fecal Coliform		Coliphage		Fecal Streptococci		Pseudomonas		Clostridium Perfringens	
	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)
M1-1	−.19	.13												
M1-2	X		X		−.032	.020								
M1-3	−.014	.010	−.0316	.0066	−.023	.070	X							
M1-4			−.33	.44							X			
M1-5	−.018	.030	−.383	.023	−.227	.079	X				X		X	
M1-6	X		−.062	.019	X		−.108	.088	X		−.02	.12	X	
M1-7	X		−.003	.013	X		X				−.003			
M1-8	−.042	.036	−.089	.039			−.051	.021			X		X	
M1-9	−.134	.070	−.025	.032	−.072	.017	X		−.081	.046	X		−.118	.047
M1-10	−.165	.070	−.094	.023	−.144	.039	−.065	.041	X		X		−.039	.052
M1-11	−.0050	.0038	−.077	.014	−.068	.017	−.0078	.0049	−.022	.017	−.005		X	
M1-12	X		−.093	.042			−.022	.016	X				−.048	.037
M1-13	X		X				−.008	.011	−.039	.15	−.17	.13	X	
M1-14			−.025	.013			−.016	.011	X				−.020	.049
M1-15			X		−.021	.012	X		X		X		−.018	.01[illegible]
M1-31	X		−.0081	.0028	−.0073	.0019	−.0037	.0078	X		X		−.0036	.0062
M1-32	X		X		X		−.15	.13						
M1-33	−.037	.037	X				−.19	.25	X					
M1-34			−.095	.043	X				X		X			
M1-35	−.004	.017	−.0497	.0053	−.063	.015	−.028	.014	X		−.014	.015		

X Viability decay rate estimate was positive slower die-off rates, cannot be quantified based on the Pleasanton study. Table VI.C-10 suggests that $-0.01s^{-1}$ to $-0.02s^{-1}$ was the lowest viability decay rate which could be detected at Pleasanton. For the hardier and infrequently measured microorganisms, such as mycobacteria, *Pseudomonas*, and fecal streptococci, perhaps $-0.06s^{-1}$ was the lowest detectable viability decay rate.

Because λ is an exponential multiplier, $e^{2\lambda a} = (e^{\lambda a})^2$; doubling the decay rate λ squares the exponential decay factor. Thus, when considering sizable aerosol ages, even differences in λ of a factor of two have a substantial effect. Using an average wind speed of 4 m/s, the median viability decay of total coliform per 100 meters (25s) is $\exp(-.032s^{-1} \times 25s) = 0.45$, slightly more than a two-fold reduction per 100 meters. The quartile viability decay of total coliform per 100 meters is $\exp(-.094s^{-1} \times 25s) = 0.10$, a ten-fold reduction per 100 meters. The corresponding decay rates for coliphage (a median 30 percent reduction per 100 meters and a quartile 3-1/2 fold reduction per 100 meters) are substantially less. Consequently, Table VI.C-10 indicates that age decay is considerably more rapid and prevalent for the coliforms than for coliphage, *Clostridium perfringens*, and standard bacterial plate count. The pathogens fecal streptococci, *Pseudomonas*, and mycobacteria seldom exhibited detectable die-off with aerosol age.

Table VI.C-7.
RUN ESTIMATES OF MICROORGANISM GROUP VIABILITY DECAY RATE λ AND STANDARD ERROR SE(λ), s^{-1}
b. Post-Fair Runs

Aerosol Run Number	Standard Plate Count		Total Coliform		Coliphage		Fecal Streptococci		Mycobacteria	
	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)	$\hat{\lambda}$	SE($\hat{\lambda}$)
M2-1	-.0044	.0039	-.0757	.0026	X		-.015	.048		
M2-2			-.014	.025	-.030	.020	X			
M2-3	X		-.0162	.0011	-.031	.024	X			
M2-4			-.0253	.0076	-.0397	.0038	-.067	.014		
M2-5			-.0082	.0038	X		X			
M2-6	-.022	.040	-.0393	.0008			X			
M2-10			X		X					
M2-11			-.033	.017	-.048	.041				
M2-12	X		-.02	.10	X		X			
M2-13			X		X		X			
M2-14			-.1137	.0079	-.055	.018	X			
M2-15	X		-.0197	.0068	-.019	.038	X			
M2-16	-.006	.027	-.0394	.0086	X		-.0062	.0078		
M2-17	X		-.0379	.0069	X		X			
M2-22	-.007	.033	-.083	.022	-.116	.050				
M2-23	X				-.008	.070				
M2-24	-.1069	.0004	-.133	.053	-.061	.033	X			
M2-25	-.090	.031	-.158	.036	-.119	.035	-.174	.017		
M2-26			-.250	.020						
M2-29	X				-.089	.023			-.009	.091
M2-30			X		X				X	
M2-31	-.0185	.0034	-.0015	.0005	-.011	.020	X		X	
M2-32	X		X		-.091	.037			X	
M2-33					X		X			
M2-34	-.010	.024			X				X	
M2-35	X		-.0077	.0032	-.0329	.0033	X		-.134	.042
M2-36			-.17		X				X	
M2-37			-.214	.039	-.042	.081	X		X	
M2-38	-.0032	.0027	-.237	.028	X		-.0127	.0068		

X Viability decay rate estimate was positive.

Table VI.C-8.
PERCENTAGE OF INDETERMINATE VIABILITY DECAY RATE ESTIMATES $(\hat{\lambda} = X)$

Microorganism Group	Number of $\hat{\lambda}$ Estimates	Percentage of Indeterminate Estimates $(\hat{\lambda} = X)$
Std. Bacterial Plate Count	33	45%
Total Coliform	44	20%
Fecal Coliform	13	31%
Coliphage	43	40%
Fecal Streptococci	31	74%
Pseudomonas	13	62%
Clostridium perfringens	11	45%
Mycobacteria	8	75%

Table VI.C-9.
RELIABILITY OF NEGATIVE VIABILITY DECAY RATE ESTIMATES $\hat{\lambda} < 0$

Microorganism Group	No. of Negative $(\hat{\lambda}, s.e.(\hat{\lambda}))$ Estimates	Percentage of Negative Estimates Exceeding	
		Two Std. Errors $\lvert t \rvert > 2$	Std. Error $\lvert t \rvert > 1$
Std. Bacterial Plate Count	18	2%	61%
Total Coliform	34	0%	85%
Fecal Coliform	9	7%	89%
Coliphage	26	1%	73%
Fecal Streptococci	8	4%	75%
Clostridium perfringens	6	3%	67%

Note: $t = \hat{\lambda}/s.e.(\hat{\lambda})$.

Table VI.C-10.
DISTRIBUTIONS OF VIABILITY DECAY RATE λ, s^{-1}

Viability Decay Rate λ, s^{-1}	Number of Estimates (Aerosol Runs)	Distribution of Values - Percentiles									
Microorganism Group		5%	10%	(20%)	25%	40%	50%	60%	75%	90%	95%
Total Coliform	44	-.31	-.23		-.094	-.050	-.032	-.020	-.004(?)	X	X
Fecal Coliform	13		-.19		-.070	-.045	-.023	-.016(?)	X	X	X
Coliphage	43	-.14	-.11		-.051	-.029	-.011	X	X	X	X
Clostridium Perfringens	11		-.10		-.038	-.019	-.004(?)	X	X	X	
Std. Bacterial Plate Count	33	-.17	-.12		-.020	-.006	-.004(?)	X	X	X	X
Mycobacteria	8		~-.15	-.027(?)	-.009(?)	X	X	X	X		
Pseudomonas	13		-.077	-.016(?)	-.008(?)	X	X	X	X	X	
Fecal Streptococci	31	-.12	-.060(?)	-.014(?)	-.006(?)	X	X	X	X	X	X

X -- Indeterminate viability decay rate.

~v -- Extrapolated value v.

v(?) -- Questionable value, perhaps indistinguishable from 0.

5. Prediction Using the Microbiological Dispersion Model

Equation (3) and the data from Tables VI.C-6 and VI.C-10 define the microbiological dispersion model. Considerations involved in using this model to predict the microbiological aerosol concentrations P downwind of any spray irrigation site are discussed in this section.

a. *Usage Considerations*

(1) Assumptions

In developing and using the microbiological dispersion model, several assumptions are made.

- The major physical and biological processes that affect microorganism aerosol levels emanating from a sprayed wastewater source are adequately represented by the multiplicative form of the microbiological dispersion model equation (3) out to distances of 500 meters to 1000 meters (aerosol ages of 100 seconds to 500 seconds) from the spray location.
- The die-off of a microorganism group that occurs during aerosolization and transport in the aerosol state is caused by factors such as meteorological conditions that have the same effect at any spray irrigation site. Thus, a given level of the controlling factors will produce the same reduction in viable aerosolized microorganisms (i.e., yield the same values of the parameters I and λ) at any spray site.
- The microbiological aerosol concentrations obtained in field studies vary somewhat depending on the sampling, shipping, and assay procedures employed. Since the distributions of the microbiological parameters I and λ were derived from the Pleasanton study, the concentrations P predicted by the model assume the use of the methods of the Pleasanton study (high volume electrostatic precipitator samplers, special and standard assay methods, etc.).

(2) Procedure

Several steps are involved in the process of predicting microorganism aerosol concentrations P in the wastewater aerosol downwind from a spray irrigation site under specified meteorological conditions using the microbiological dispersion model.

- *Microorganism Wastewater Concentrations*. Select the prevalent and relevant microorganism group(s) and determine typical microorganism concentrations in the wastewater.
- *Diffusion Model Aerosol Concentration D*. Apply an appropriate atmospheric dispersion model to project each microorganism wastewater concentration to its corresponding diffused aerosol concentration at the downwind location. Validated atmospheric dispersion models of varying sophistication(50,54,55,56,57) are available to calculate D. Model input generally includes the configuration of sprayers, spray trajectory, wastewater spray rate, the microorganism wastewater concentrations, pertinent meteorological conditions for the case considered, the local topography, and the distance to the downwind location. Usually the centerline (peak) concentration at the downwind distance is computed as D.

- *Aerosolization Efficiency E.* Select an aerosolization efficiency estimate for the case considered based on the type of spray equipment, spray head pressure, and pertinent meteorological factors. Once a median estimate of E is developed for a spray site, equation (5) may be used to help select an E value for the case based on the specified meteorological conditions.
- *Impact Factor I and Viability Decay Rate λ.* For each microorganism group, select the proper I and λ percentile values from their distributions given in Tables IV.C-6 and IV.C-10. Section V, Discussion, provides guidance in choosing the proper percentile based on the relevant meteorological conditions. Because of uncertainties in the estimation process, selecting values of I and λ outside their middle ranges (25th to 75th percentiles) is not recommended.
- *Predicted Microorganism Aerosol Concentration P.* The predicted microorganism concentration in the wastewater aerosol is then calculated from the estimates of D, E, I, and λ using equation (3).

b. Examples

(1) Pleasanton Residential Example

The microbiological dispersion model was used to obtain order-of-magnitude estimates of the microorganism aerosol concentrations to which the residents are typically exposed in the Pleasanton subdivision nearest the spray fields. The edge of this subdivision is located about 650 meters east and southeast from the edges of the nearest spray fields.

The model input conditions, parameter values, and predicted aerosol concentrations are presented in Table VI.C-11 for a typical summer nighttime case for total coliform, mycobacteria, and enteroviruses. Typical observed values were used for the wastewater concentrations and wastewater spray rate. The H. E. Cramer Company Volume-Source Diffusion Models Program was used to calculate the centerline concentration D for each microorganism group at the subdivision edge, taking into account the orientation of the sprayer line when the subdivision would be downwind. A median aerosolization efficiency E = 0.0033 was obtained from equation (5). As will be discussed later in the Discussion Section, the set of meteorological conditions for this summer nighttime case tends to be associated with values of both I and λ in the upper tails of their distributions. Thus, the 60th percentile values of I in Table VI.C-6 and of λ in Table VI.C-10 were selected as typical values for the three microorganism groups. The centerline aerosol concentrations P predicted at the subdivision edge are 0.01 mfc/m^3 for total coliform, 0.09 cfu/m^3 for mycobacteria, and 0.006 pfu/m^3 for enteroviruses.

As a comparison, the aerosol concentrations of these microorganism groups at the subdivision edge are also presented for a typical summer midday case in Table VI.C-12. Equation (5) yields an aerosolization efficiency E = 0.016 for these meteorological conditions. Since the summer midday conditions tend to give I and λ values in the lower tails of their distributions, 40th percentile values for the microorganisms were selected for this typical midday case. The predicted centerline aerosol concentrations were 0.001 mfc/m^3 for total coliform, 0.06 cfu/m^3 for mycobacteria, and 0.002 pfu/m^3 for enteroviruses.

(2) Deer Creek Campsite Example

The microbiological dispersion model can also be applied at other spray irrigation sites. For example, one can obtain order-of-magnitude estimates of the microorganism level extremes to which

Table VI.C-11.
PREDICTION OF TYPICAL NIGHTTIME MICROORGANISM AEROSOL LEVELS ENTERING PLEASANTON RESIDENTIAL AREA

Model Input Conditions	Summer Nighttime Case		
Season and Time	summer night		
Air Temperature	20° C		
Relative Humidity	70%		
Solar Radiation	0 W/m^2		
Wind Velocity	2 m/s		
Stability Class	E		
Mixing Height	30 m		
Residential Distance	650 m		
Residential Direction	E to SE		
Aerosol Age, a	325 s		
Wastewater Spray Rate	70 ℓ/s		
MICROORGANISM GROUP	Total Coliform	Mycobacteria	Enteroviruses
Wastewater Concentration	1×10^7 mfc/ℓ	80,000 cfu/ℓ	50 pfu/ℓ
Model Parameter Values			
D (Centerline)	12,000 mfc/m^3	100 cfu/m^3	0.06 pfu/m^3
E	0.0033	0.0033	0.0033
I	0.23	1.0	60
λ	-0.020 s^{-1}	-0.004* s^{-1}	-0.002* s^{-1}
$e^{\lambda a}$	0.0015	0.27	0.52
Predicted Aerosol Concentration			
P (Centerline)	0.01 mfc/m^3	0.09 cfu/m^3	0.006 pfu/m^3

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*Interpolated value between the quantified range of the model parameter and zero.

Table VI.C-12.
PREDICTION OF TYPICAL MIDDAY MICROORGANISM AEROSOL LEVELS ENTERING PLEASANTON RESIDENTIAL AREA

	Summer Midday Case		
Model Input Conditions			
Season and Time	summer midday		
Air Temperature	30° C		
Relative Humidity	40%		
Solar Radiation	1000 W/m^2		
Wind Velocity	4 m/s		
Stability Class	B		
Mixing Height	High		
Residential Distance	650 m		
Residential Direction	E to SE		
Aerosol Age, a	162.5 s		
Wastewater Spray Rate	70 ℓ/s		
MICROORGANISM GROUP	Total Coliform	Mycobacteria	Enteroviruses
Wastewater Concentration	1 x 10^7 mfc/ℓ	[illegible],000 cfu/ℓ	50 pfu/ℓ
Model Parameter Values			
D (Centerline)	1800 mfc/m^3	15 cfu/m^3	0.009 pfu/m^3
E	0.016	0.016	0.016
I	0.13	0.82	30
λ	-0.050 s^{-1}	-0.007* s^{-1}	-0.004* s^{-1}
$e^{\lambda a}$	0.0003	0.32	0.52
Predicted Aerosol Concentration			
P (Centerline)	0.001 mfc/m^3	0.06 cfu/m^3	0.002 pfu/m^3

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*Interpolated value between the quantified range of the model parameter and zero.

campers are exposed at an 80-100 trailer campsite located from 700 to 900 meters northeast of the spray field at Deer Creek Lake, Ohio.

Spray irrigation is accomplished at Deer Creek Lake with 96 Rainbird impact sprayers arranged in an 8 × 12 grid in a 3-acre square field (sides of 150 meters). The U.S. Army conducted a field sampling and assay program at the Deer Creek Lake site in the summer of 1976(58). Wastewater samples were assayed routinely for indicator microorganisms and occasionally for pathogens. The microbiological aerosol runs were performed using twelve Andersen samplers and two Litton Model M high volume samplers, with samples only assayed for total aerobic bacteria. Four dye aerosol runs using fluorescein dye were also made.

Predictions of campsite microorganism aerosol level extremes emanating from the spray field made by using the microbiological dispersion model are presented in Table VI.C-13 for a daytime and a nighttime case. Typical values for the site were used for the wastewater concentrations of total coliform and fecal streptococci and for the wastewater spray rate. Calculations based on applying the Volume-Source Diffusion Models Program to the sampling data(59) were used to estimate the centerline concentration D at the campsite edge and typical aerosolization efficiencies E for the daytime and nighttime cases. Considering the meteorological conditions, the extreme values selected for I and λ were the 25th percentiles for the daytime case and the 75th percentiles for the nighttime case. The predicted extreme daytime and nighttime aerosol concentrations P at the campsite edge are, respectively, 2×10^{-9} and 0.05 cfu/m^3 for total coliform, and 0.0004 and 0.01 cfu/m^3 for fecal streptococci.

6. Preliminary Evaluation of Distance and Solar Radiation Factors

Prior to developing the microbiological dispersion model, several preliminary analyses of the aerosol concentration data were performed to investigate some of the fundamental assumptions of the model. These analysis results are presented in detail in Appendix G. The following synopsis indicates the purpose and findings of each analysis.

a. Analysis of Variance

The significance of distance and solar radiation as factors affecting microbiological aerosol levels was investigated by analysis of variance of the Post-Fair data. Except for the standard bacterial plat count, aerosol levels varied significantly with sampler distance. The aerosol levels of standard bacterial plate count, total coliform, and fecal streptococci were significantly reduced on runs made during high solar radiation.

b. Source and Distance Analysis

The pairs of aerosol measurements from two sampler locations were compared using paired comparison tests. Comparison of upwind versus close downwind connentrations demonstrated that the spray line was a significant aerosol source of each of the microorganism groups monitored. Comparison of close downwind versus distance downwind data only yielded signfficant aerosol concentration decreases with distance for total coliform, fecal coliform, coliphage, and fecal streptococci. Failure to find a significant decrease with distance for the other microorganism groups reflects the variability of their aerosol concentration measurements and/or a small number of runs.

7. Preliminary Assessment of Factors Affecting Microbiological Aerosol Levels

A preliminary assessment was conducted after the Pre-Fair sampling of the environmental factors affecting microbiological aerosol levels on the Pre-Fair aerosol runs. Stepwise multiple linear regression was used to select, from a large list of plausible candidates, these environmental variables in the D, E, I, and λ categories which best fit the microorganism aerosol data. A full description of the analysis and its results is given in Appendix G.

Table VI.C-13.

PREDICTION OF MICROORGANISM AEROSOL LEVEL EXTREMES ENTERING DEER CREEK LAKE CAMPSITE

	Daytime Case		Nighttime Case	
Model Input Conditions				
Season and Time	summer midday		summer night	
Air Temperature	30° C		20° C	
Relative Humidity	40%		70%	
Solar Radiation	1,000 W/m^2		0 W/m^2	
Wind Velocity	4 m/s		2 m/s	
Stability Class	B		E	
Mixing Height	high		30 m	
Residential Distance	700 m		700 m	
Residential Direction	NNE to ENE		NNE to ENE	
Aerosol Age, s	175 s		350 s	
Wastewater Spray Rate	30 ℓ/s		30 ℓ/s	
MICROORGANISM GROUP	Total Coliform	Fecal Streptococci	Total Coliform	Fecal Streptococci
Wastewater Concentration	180,000 cfu/ℓ	1,000 cfu/ℓ	180,000 cfu/ℓ	1,000 cfu/ℓ
Model Parameter Values				
D (Centerline)	40 cfu/m^3	0.2 cfu/m^3	100 cfu/m^3	0.6 cfu/m^3
E	0.009	0.009	0.004	0.004
I	0.06	0.71	0.55	6.1
λ	$-0.094\ s^{-1}$	$-0.006\ s^{-1}$	$-0.004\ s^{-1}$	-0.001* s^{-1}
$e^{\lambda a}$	7×10^{-8}	0.35	0.25	0.70
Predicted Aerosol Concentration				
P (Centerline)	$2 \times 10^{-9}\ cfu/m^3$	0.0004 cfu/m^3	0.05 cfu/m^3	0.01 cfu/m^3

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* Interpolated value between the quantified range of the model parameter and zero.

Similar factors were identified as explaining much of the observed variation in the aerosol levels of total coliform, fecal coliform, and coliphage. The diffusion model D was found to be important for all three microorganisms. Temperature was indicated to have an important effect on wastewater aerosolization efficiency, while low pond relative humidity and middle upwind relative humidity both had lethal impact effects. Viability decay occurred primarily at middle relative humidities and at high temperature.

There is some evidence that the three pathogenic bacteria, *Pseudomonas*, fecal streptococci, and *Clostridium perfringens*, may also be affected by similar environmental variables. All appear to be initially reduced in viability by strong, dry winds. Desiccation also appears to play a role in their viability decay with aerosol age or distance.

This preliminary assessment of environmental factors was important, both becuase it justified the form of the microbiological dispersion model equation (3), and because it represents the most comprehensive analysis to date of the effects that atmospheric and operating conditions have on the microorganism-specific parameters I and λ, and thereby on the aerosol concentration.

D. Evaluation of the Microbiological Dispersion Model

The predictive value of the microbiological dispersion model is determined by how well its prediction, P, of the microorganism aerosol concentration from a spray source agrees with C-B, the measured concentration corrected for background. In this section, model predictions are compared to the aerosol concentration data from the Pleasanton runs, which were not used in the model development, and from field sampling programs conducted at Deer Creek Lake, Ohio(60) and Fort Huachuca, Arizona(61,62,63). Information is presented on the accuracy and precision of the model predictions.

1. Evaluation Data

To evaluate the suitability of the model for a microorganism group, it is necessary to obtain many pairs (C-B,P) of the net measured concentration, C-B, and the model-predicted concentration, P, for the microorganism group from various distances, runs and sites. Consistent procedures were used for calculating values of C-B and P and for deciding whether to use these values in the model evaluation.

From the Pleasanton sampling program, the smoothed concentration values, C , not used in developing the microbiological dispersion model, were potentially usable in the model evaluation. These consisted of a few values from the microbiological aerosol runs in the tables of Appendix F and all the quality assurance run values (Tables VI.B-16 through VI.B-23). Nearly all the concentration values above background from the Deer Creek Lake and Fort Huachuca sampling programs were potentially usable in the model evaluation. The exceptions were several cases of presumed contamination in which very high outlier values relative to the surrounding values were obtained, and several cases in which chlorinated effluent was sampled. At all sites, a line of samplers, or at least a pair of samplers, was often located at the same distance from the spray source. Sometimes a pair of samplers consisted of one high-volume aerosol sampler and one Andersen sampler. At Ft. Huachuca, several downwind samplers were deployed along an arc at 10° to 40° intervals at the same distance from the single spray source. These situations were treated by averaging the concentrations from paired high-volume and Andersen samplers, by averaging the concentrations along a line of samplers, and by averaging the concentrations over an arc of samplers. Thus, no more than one net concentration value, C-B, was used at a given sampler distance on a run. The measured concentration values from all sites were used for model evaluation only if they exceeded both the run background ($C\text{-}B > 0.5B$) and the minimum detection limit ($C\text{-}B > DL$).

Predicted values corresponding to the net measured concentration value were computed from equation (3), $P = D \bullet E \bullet I \exp(\lambda \bullet a)$, using the procedures given in Section VI.C.5.a.2. Diffusion model aerosol concentrations at each sampler position were calculated by H.E. Cramer Company, using their Volume Source Diffusion Model.[64] Calculation of aerosolization efficiency from the dye runs at Deer Creek Lake and Fort Huachuca, using equation (4) $E = C/D$, with Cramer's modeled D values, showed that the aerosolization efficiencies of the Deer Creek Lake and Fort Huachuca spray systems were similar to Pleasanton. Consequently the aerosolization efficiency, E, during each microbiological run at Deer Creek Lake and Fort Huachuca was computed from equation (5).

The solar radiation measurement, r, used in equation (5) should be recorded by a short-wave instrument of the vertical Eppley-type for consistency with the Belfort short-wave instrument used at Pleasanton. The incoming radiometer readings, in millivolts, from the Deer Creek Lake and Fort Huachuca reports, were adjusted to equivalent short-wave values based on hourly cumulative vertical-Eppley readings provided by Mr. Marrison of the Atmospheric Sciences Laboratory, White Sands, New Mexico. A percentile of the I and λ distributions was selected for each run following the guidance given in Section VII, below. Solar radiation was used as the primary criterion in selecting the 25th, 40th, 50th, 60th or 75th percentile, with consideration occasionally given to additional factors, such as run selectivity at Pleasanton and effluent chlorination at Fort Huachuca. In a few cases, no predicted value could be computed to correspond to a C-B value, either because the run was not diffusion-modeled or because no wastewater concentration was measured.

The numbers of data pairs (C-B,P) for the model evaluation are presented in Table VI.D-1 by microorganism group and site. The first column gives the number of pairs for which a detectable measured value and model prediction were obtained; these are the potential evaluation data. The number of these pairs, for which the measured concentration is detectable ($C\text{-}B > 0.5B$ and $C > DL$) is given in the second column; these pairs were used to evaluate the precision of the model predictions. The number of these pairs for which the predicted concentration would also be detectable ($P > 0.5B$ and $P > DL$) is shown in the next column; these were used to analyze the accuracy of the model predictions. Table VI.D-1 shows that standard bacterial plate count, total coliform, and possibly coliphage are the only microorganism groups having enough data pairs to perform an adequate model evaluation. For the other microorganism groups, nearly all of the usable data pairs come from the Pleasanton sampling program.

It should be noted that the sampling and analytical methods used at Deer Creek Lake and Fort Huachuca differed from those employed at Pleasanton. The aerosol samplers for the Deer Creek Lake and Fort Huachuca runs were mainly six-stage Andersen samplers supplemented by one or two high-volume aerosol samplers, whereas only high-volume samplers were used at Pleasanton. Presumptive identification of total coliforms using Endo agar or Endo broth was used at Deer Creek Lake and Fort Huachuca; at Pleasanton, presumptive total coliforms on lactose broth were confirmed on brilliant green bile . At Fort Huachuca, coliphage measurements were obtained by seeding the wastewater with coliphage f2 and sampling this aerosol with Andersen and high-volume samplers. Since laboratory studies indicated that the recovery efficiency of airborne f2 from Andersen samplers was about 25 percent of that of liquid impaction samplers,[65] the field coliphage f2 concentrations obtained with the Andersen samplers were multiplied by four. At Pleasanton, the natural coliphage present in the wastewater were sampled and assayed. The preceding differences might affect the model evaluation, since the I and λ coefficients of the microbiological dispersion model are based on the Pleasanton sampling and analytical methods.

Each data pair used in the model evaluation (i.e. those with detectable measured net concentrations C-B for which totals are given in the second column of Table VI.D-1) is tabulated in Appendix H. The tables of Appendix H are arranged by microorganism group, site, and analytical method. Displayed in the Appendix H tables for each data pair are the aerosol run number, key meteorological parameters (temperature, relative humidity, solar radiation, and wind velocity), the selected percentile of the I and λ distributions, the measured aerosol concentration, C-B, the model-predicted aerosol concentration, P, and the orders of magnitude of discrepancy statistic, OMD.

In comparing the measured and predicted aerosol concentrations, proportional differences are more relevant than absolute differences. For example, the discrepancies between the microorganism aerosol concentration pair (10,000/m^3 vs. 1,000/m^3) and between the pair (10/m^3 vs. 1/m^3)might be considered

Table VI.D-1.
NUMBER OF DATA PAIRS FOR MODEL EVALUATION

Microorganism Group / Site	Number of Data Pairs: Run/Distance Combinations Measured and Modeled	Detectable* Measured Concentrations Number	Detectable* Measured and Predicted Concentrations Number	Effective No†
Std. Bacterial Plate Count				
Pleasanton	9	7	6	6
Deer Creek Lake	60	54	45	28.5
Ft. Huachuca	50	37	34	24.5
All Sites and Methods	119	98	85	59
Total Coliform				
Pleasanton	8	8	8	8
Presumptive on Endo Agar:				
Ft. Huachuca	30	24	17	13.5
Presumptive on Endo Broth:				
Deer Creek Lake	10	8	0	0
Ft. Huachuca	13	9	7	6.5
All Endo Broth	23	17	7	6.5
All Sites and Methods	61	49	32	28
Fecal Coliform				
Pleasanton	6	5	5	5
Ft. Huachuca	4	2	1	1
All Sites and Methods	10	7	6	6
Coliphage				
Pleasanton	5	5	5	5
Ft. Huachuca (seeded f2)	16	15	15	10.5
All Sites and Methods	21	20	20	15.5
Fecal Streptococci				
Pleasanton	10	8	8	8
Ft. Huachuca	8	2	0	0
All Sites and Methods	18	10	8	8
Pseudomonas				
Pleasanton	4	4	4	4
Clostridium perfringens				
Pleasanton	3	2	2	2
Mycobacteria				
Pleasanton	5	4	4	4

* Above background ($C-B \geq 0.5B$, $P > 0.5B$) and detection limit ($C \geq DL$, $P \geq DL$), and excluding presumably contaminated samples.

† Presumed equivalent number of independent observations.

equivalent because both are "factor of 10" or "one order of magnitude" discrepancies. Hence, the model evaluation is based on these two proportional difference statistics which are easily interpreted. The discrepancy factor statistic, F, is defined as the larger of (C-B)/P and P/(C-B):

$$F = \mathrm{Max}\left(\frac{C-B}{P}\ ,\ \frac{P}{C-B}\right) \tag{14}$$

The orders of magnitude of discrepancy statistic is defined as:

$$\mathrm{OMD} = \log_{10}\left(\frac{C-B}{P}\right) \tag{15}$$

These statistics are mathematically related since $\mathrm{OMD} = \log_{10}F$ and $F = 10^{|\mathrm{OMD}|}$. Thus, three orders of magnitude discrepancy ($\mathrm{OMD} = \pm 3$) is equivalent to a discrepancy factor of 1000 : $F = 10^3 = 1000$.

A scan of the Appendix H tables shows that the greater majority of model predictions differ from the measured aerosol concentrations by less than an order of magnitude ($-1 < \mathrm{OMD} < 1$). The accuracy and precision of the model predictions are more fully characterized in the following sections.

Applicability of the model to chlorinated effluent aerosols can be inferred from the model predictions for standard bacterial plate count on several runs at Fort Huachuca, in which the effluent was chlorinated prior to spraying. The results are presented in Table VI.D-2. Measurement of the aerosol concentrations of standard bacterial plate count on the chlorinated runs is quite uncertain, because the low net measured concentrations of nearly 0 to 30/m³ were less than the measured background concentrations of 19 to 170/m³ on each run, except Run 74-6. Also, the diffusion modeling of some of these runs could only provide approximate concentrations because the wind direction varied so widely. Yet the microbiological dispersion model regularly predicted an aerosol concentration several orders of magnitude lower than the measured value ($\mathrm{OMD} \geqslant +1.5$). The marked underprediction with chlorinated effluent contrasted with the relatively

Table VI.D-2

COMPARISON OF MODEL PREDICTIVE ABILITY OF CHLORINATED AND UNCHLORINATED EFFLUENT

	Aerosol Run Number	Wastewater Chlorination (mg/l)		Standard Bacterial Plate Count			OMD
		Total	Free	Effluent (CFP/ml)	Aerosol Conc (CFP/m) C-B	P	$\log_{10}\left(\frac{C-B}{P}\right)$
Average Chlorination (Ft. Huachuca)							
	74-5	6.3	1.5	50	2.3	0.08	+1.5
	74-6	0.8	0.0	220	30	0.05	+2.8
	75-6	6.0	0.7	88	29	0.06	+2.7
	75-5	6.5	0.8	87	5	0.05	+2.0
	75-15	6.0	0.6	50	0	0.4	?
Low Chlorination (Deer Creek Lake)	45 pairs	0.1-0.4	--	29,000			+0.26
Unchlorinated (Ft. Huachuca)	34 pairs	--	--	310,000			+0.14
Unchlorinated (Pleasanton)	6pairs	<0.1	<0.05	610,000			+0.02

good model predictions for low chlorination, and especially for unchlorinated effluents, are summarized in Table VI.D-2. Thus, it appears that the microbiological dispersion model does not give valid predictions of microbiological aerosol concentrations from highly chlorinated effluents.

An hypothesis is offered to explain model underprediction for chlorinated effluent aerosols. The types of microorganisms that are most susceptible to die-off during aerosolization may be the same types that are generally killed by chlorination of wastewater. Hence, little impact die-off would occur ($I \approx 1$) during aerosolization of chlorinated effluent.

2. Accuracy of Model Predictions

The predictions of the model will intuitively be regarded as being accurate if the predicted microorganism concentrations fall randomly above and below the net measured concentrations with no detectable bias. It is assumed that each OMD calculated from equation (15) for a group of data pairs is sampled from the same normal distribution with unknown population mean μ_{OMD} and variance σ^2_{OMD}. If the mean μ_{OMD} is not significantly different from 0, the model predictions may be considered accurate in a statistical sense. The null hypothesis of model prediction accuracy ($\mu_{OMD} = 0$) can be tested against the two-sided alternative, $\mu_{OMD} \neq 0$, using the test statistic $t = \overline{OMD}/(S_{OMD}/\sqrt{n})$ which has the t distribution with n-1 degrees of freedom, provided the OMD's are independent observations from the same normal distribution. Here $\overline{OMD} = (\Sigma \, OMD)/n$ and $S^2_{OMD} = \Sigma \, (OMD - \overline{OMD})^2/(n - 1)$ are the sample mean and sample variance, respectively.

An analysis of model prediction accuracy using the t statistic was conducted for each microorganism group at each site and for the total OMD observations for each microorganism group over all three sites. To prevent an artificial selection bias, the accuracy analysis was based on those data pairs from the Appendix H tables, for which both the net measured concentrations and the predicted concentrations were detectable.

A scan of the Appendix H data reveals that the OMD values of a microorganism group for the different sampling distances on an aerosol run are related. The OMD values at the various sampler distances on a run all tend to have similar values, especially for samplers that were located close to each other. Consider, for example, the OMD values for standard bacterial plate count from the Deer Creek Lake study on Run 15 [—0.25 (30m), —0.39 (50m)] and on Run 16 [0.84 (30m), 0.88 (50m), 0.78 (200m)]. Since the OMD values at different distances on a run are similar, the OMD values obtained for a group are not independent observations, as is assumed in calculating a probability value for the t statistic by the usual procedure. Because the OMD values for a run are related, in effect there are less than n independent observations in a group of data pairs. The "effective number of independent observations" was calculated by assuming that runs with OMD values at three sampler distances provided two independent observations, that runs with OMD values at two distances provided one and one half independent observations, and that runs with a single OMD value contributed one independent observation. Both the actual number of OMD values and the presumed effective number of independent observations are presented in the last two columns of Table VI.D-1 for each group of detectable measured and predicted concentrations on which an accuracy analysis was conducted. The t statistic and its two-sided significance level (p) were computed for both the number of observations and the effective number of independent observations. Although similar values were obtained for both cases, the effective number is regarded as more valid, and inferences are based on this procedure.

Provided the number of independent observations is correctly determined, the p value is the probability of getting a more discrepant t statistic than the value obtained for a random sample of equal size from a population with zero mean ($\mu_{OMD} = 0$). Thus, p indicates the accuracy of the model predictions relative to the net measured aerosol concentration. A p value above 0.20 suggests little or no consistent bias, while a p value below 0.05 suggests there is a consistent bias in the model predictions.

The results of the accuracy analyses for standard bacterial plate count, total coliform, fecal coliform, coliphage, and the pathogenic microorganisms are presented respectively in Tables VI.D-3 through VI.D-7. The geometric mean of the P/(C-B) ratios is tabulated to indicate the average discrepancy between the predicted and measured values. The OMD provides another measure of this discrepancy. For groups in which the number of detectable data pairs differed from the effective number of independent observations, the t statistic and its two-sided p value are presented for both cases.

Table VI.D-3 shows that the accuracy of the model predictions for standard bacterial plate count differ considerably among the study sites. At Pleasanton, there is no evidence of bias in the model predictions. At Fort Huachuca, the model predictions tended to be 72 percent as large as the measured net concentrations, but there was sufficient variability that no consistent bias was detected ($p = 0.16$). At Deer Creek Lake, the model predictions of standard bacterial plate count were consistently ($p = 0.0016$) less than the measured values, averaging 55 percent as large. Referring to Table VI.D-2, the slight model prediction underestimation with low chlorination at Deer Creek Lake is consistent with the apparent two orders of magnitude model underestimation for heavily chlorinated Fort Huachuca effluent. Thus, chlorination may be responsible for the slight underprediction at Deer Creek Lake. The summarized results over all three sites are similar to those for Deer Creek Lake, which provided the majority of the data pairs. With $p = 0.0012$, the model predictions of standard bacterial plate count were found to be consistently smaller than the measured values, averaging 64 percent as large.

Table VI. D-3

ANALYSIS OF THE ACCURACY OF STANDARD BACTERIAL PLATE COUNT MODEL PREDICTIONS

	Sites			All Sites and Methods
	Pleasanton	Deer Creek Lake	Ft. Huachuca	
Number of Detectable* Measured and Predicted Concentration Pairs	6	45	34	85
$\frac{P}{C-B}$ Geometric Mean	0.95	0.55	0.72	0.64
OMD Mean, $\overline{OMD}$	0.02	0.26	0.14	0.20
OMD Standard Deviation	0.56	0.40	0.48	0.45
$t = \overline{OMD}/(S_{OMD}/\sqrt{n})$	0.02	4.40	1.72	4.08
p value (two-sided)	>0.90	0.00005	0.10	0.0001
Effective+ Number	6	28.5	24.5	59
$t = \overline{OMD}/(S_{OMD}/\sqrt{n'})$		3.50	1.46	3.40
p value (two-sided)		0.0016	0.16	0.0012

Orders of Magnitude of Discrepancy, $OMD = \log_{10}\left(\frac{C-B}{P}\right)$

*Above background ($C-B \geqslant 0.5B$, $P > 0.5B$) and detection limit ($C \geqslant DL$, $P \geqslant DL$), and excluding presumably contaminated samples.

+ Presumed equivalent number of independent observations.

The analysis given in Table VI.D-4 provides no evidence of a consistent bias in model predictions of total coliform aerosol concentration. With unchlorinated wastewater aerosols assayed for confirmed total coliforms at Pleasanton and for presumptive total coliforms at Fort Huachuca both on Endo agar and on Endo broth, no consistent proportional differences were found between the measured values and the model predictions. Thus, prediction of total coliform aerosol concentrations with the microbiological dispersion model for unchlorinated wastewater aerosols apparently yields accurate estimates of the measured values that could be obtained using a variety of aerosol sampler types and assay methods.

Accuracy analysis of fecal coliform model predictions in Table VI.D-5 shows that the model tends to underestimate measured fecal coliform aerosol concentrations by about a factor of $1/0.40 = 2.5$. The impact factor distribution, I, for fecal coliform is based on only 13 Pre-Fair aerosol runs at Pleasanton, which may be insufficient to characterize this distribution.

The accuracy analysis in Table VI.D-6 indicates that model predictions of total coliphage aerosol concentrations tended to overpredict the measured values at Pleasanton by a factor of 2.4, while possibly underpredicting seeded coliphage aerosol concentrations at Fort Huachuca at about half the measured value. However, considering both sites together, there is no evidence of consistent prediction bias.

Table VI. D-4
ANALYSIS OF THE ACCURACY OF TOTAL COLIFORM MODEL PREDICTIONS

	Assay Methods			
	Confirmed	Presumptive		
		Endo Agar	Endo Broth	All Sites and Methods
	Pleasanton	Ft. Huachuca	Ft. Huachuca	
Number of Detectable* Measured and Predicted Concentration Pairs	8	17	7	32
$\frac{P}{C-B}$ Geometric Mean	1.38	0.62	0.52	0.73
OMD Mean, $\overline{OMD}$	-0.14	0.21	0.28	0.14
OMD Standard Deviation	0.55	0.51	0.63	0.55
$t = \overline{OMD}/(S_{OMD}/\sqrt{n})$	-0.71	1.67	1.17	1.39
p value (two sided)	~ 0.50	0.13	~ 0.30	0.18
Effective⁺ Number	8	13.5	6.5	28
$t = \overline{OMD}/(S_{OMD}/\sqrt{n'})$		1.49	1.13	1.30
p value (two sided)		0.16	~ 0.30	0.21

Orders of Magnitude of Discrepancy, $OMD = \log_{10}\left(\frac{C-B}{P}\right)$

*Above background ($C-B \geqslant 0.5B$, $P > 0.5B$) and detection limit ($C \geqslant DL$, $P \geqslant DL$), and excluding presumably contaminated samples.

⁺Presumed equivalent number of independent observations.

Analyses of the accuracy of model predictions at Pleasanton of fecal streptococci, *Pseudomonas*, *Clostridium perfringens*, and mycobacteria are given in Table VI.D-7. The analyses suggest a tendency for the model to overpredict fecal streptococci and *Pseudomonas* aerosol concentrations. However, many of the data pairs available for model evaluation of the bacterial pathogens were from "left over" runs in which few detectable measured aerosol concentrations were obtained. It appears that this bias in selecting data pairs has produced biased (C-B,P) observations that may have confounded the accuracy analysis for each of these bacterial pathogens.

The accuracy of the model predictions over all methods and sites is summarized in Table VI.D-8 for each microorganism group. An assessment of the probable bias that results from using the microbiological dispersion model to predict microorganism aerosol concentrations is given in the last column of Table VI.D-8.

Model predictions tend to slightly underestimate the standard bacterial plate count and fecal coliform aerosol concentrations, giving predictions that average about half as large as the anticipated measured values. Given the imprecision of measured aerosol concentrations of standard bacterial plate count and fecal coliform (i.e. coefficients of variation of 50 and 58 percent respectively, were presented in Table VI.B-40), and the variety of sampling methods, analytical methods, and effluent aerosols evaluated, the slight underestimation bias in model predictions of standard bacterial plate count and fecal coliform aerosol concentrations is not considered to be of practical significance.

The accuracy analysis of the model predictions of the bacterial pathogens was based on few observations (C-B,P), some of which may not be valid for assessing accuracy. Thus, the accuracy of model predictions of bacterial pathogen aerosol concentrations is still regarded as unknown.

Table VI. D-5.

ANALYSIS OF THE ACCURACY OF FECAL COLIFORM MODEL PREDICTIONS

	Sites		
	Pleasanton	Ft. Huachuca	All Sites and Methods
Number of Detectable* Measured and Predicted Concentration Pairs	5	1	6
$\frac{P}{C-B}$ Geometric Mean	0.41	0.36	0.40
OMD Mean, $\overline{OMD}$	0.39	0.44	0.40
OMD Standard Deviation	0.31		0.28
$t = \overline{OMD}/(S_{OMD}/\sqrt{n})$	2.83		3.52
p value (two-sided)	0.048		0.017

Orders of Magnitude of Discrepancy, $OMD = \log_{10}\left(\frac{C-B}{P}\right)$

*Above background (C—B ⩾ 0.5B, P > 0.5B) and detection limit (C ⩾ DL, P ⩾ DL), and excluding presumably contaminated samples.

+ Presumed equivalent number of independent observations.

Although varying results were obtained at different sites using different methods, the accuracy analyses for all sites did not detect a consistent significant bias in the model predictions of the aerosol concentrations of total coliform and coliphage. While the overall accuracy analyses involved enough (C-B,P) observations to detect a substantial bias if it had existed, only slight site-specific or nonspecific biases were found. Thus, for most model applications, the predictions of total coliform and coliphage aerosol concentrations with the microbiological dispersion model appear to be sufficiently accurate estimates of the measured aerosol concentrations that would be obtained with various types of aerosol samplers and assay methods.

3. Precision of Model Predictions

The precision of the model predictions refers to how close the predicted aerosol concentrations tend to be to the net measured aerosol concentrations regardless of which value tends to be larger. Thus, the precision of a prediction relative to C-B, can be measured in terms of the discrepancy factor statistic F defined in equation (14) or of the absolute value of the orders of magnitude of discrepancy statistic |OMD| .

An analysis of model prediction precision was conducted for each microorganism group at each site and for all three sites. All the data pairs given in the Appendix H tables (i.e., all pairs for which the measured aerosol concentration was detectable) were considered valid measures of microbiological dispersion model precision and thus were utilized in the precision analysis.

Table VI. D-6

ANALYSIS OF THE ACCURACY OF COLIPHAGE MODEL PREDICTIONS

	Sites		
	Natural Pleasanton	Seeded f2 Ft. Huachuca	All Sites and Methods
Number of Detectable* Measured and Predicted Concentration Pairs	5	15	20
$\frac{P}{C-B}$ Geometric Mean	2.4	0.49	0.73
OMD Mean, $\overline{OMD}$	-0.38	0.31	0.14
OMD Standard Deviation	0.10	0.48	0.52
$t = \overline{OMD}/(S_{OMD}/\sqrt{n})$	-8.5	2.51	1.19
p value (two-sided)	0.0011	0.0025	0.25
Effective⁺ Number	5	10.5	15.5
$t = \overline{OMD}/(S_{OMD}/\sqrt{n'})$		2.10	1.05
p value (two-sided)		0.06	~0.32

Orders of Magnitude of Discrepancy, $OMD = \log_{10}\left(\frac{C-B}{P}\right)$

*Above background ($C-B \geqslant 0.5B$, $P > 0.5B$) and detection limit ($C \geqslant DL$, $P \geqslant DL$), and excluding presumably contaminated samples.

⁺Presumed equivalent number of independent observations.

Table VI. D-7
ANALYSIS OF THE ACCURACY OF PATHOGENIC MICROORGANISM MODEL PREDICTIONS AT PLEASANTON

	Fecal Streptococci	*Pseudomonas*	*Clostridium Perfringens*	Mycobacteria
Number of Detectable* Measured and Predicted Concentration Pairs	8	4	2	4
$\frac{P}{C-B}$ Geometric Mean	4.2	5.9	7.5	0.38
OMD Mean, $\overline{OMD}$	-0.62	-0.77	-.088	0.43
OMD Standard Deviation	0.36	0.24	0.81	0.53
$t = \overline{OMD}/(S_{OMD}/\sqrt{n})$	-4.89	-6.53	-1.52	1.70
p-value (two-sided)	0.0018	0.007	~0.35	0.19

Orders of Magnitude of Discrepancy, $OMD = \log_{10}\left(\frac{C-B}{P}\right)$

*Above background ($C-B \geq 0.5B$, $P > 0.5B$) and detection limit ($C \geq DL$, $P \geq DL$), and excluding presumably contaminated samples.

' Presumed equivalent number of independent observations.

Table VI. D-8
SUMMARY OF MODEL PREDICTION ACCURACY FOR ALL SITES AND METHODS

Microorganism Group	Detectable Measured and Predicted Pairs	Factor $P/(C-B)$ Geometric Mean	Mean of Orders of Magnitude of Discrepancy	P Value (two-sided) for Effective No. of Obs.	Assessment of Prediction Bias
Standard Bacterial Plate Count	85	0.64	0.20	0.0012	slight underestimate
Total Coliform	32	0.73	0.14	0.21	unbiased
Fecal Coliform	6	0.40	0.40	0.017	slight underestimate
Coliphage	20	0.73	0.14	~ 0.32	unbiased
Fecal Streptococci	8	4.2	-0.62	0.0018	unknown
Pseudomonas	4	5.9	-0.77	0.007	unknown
Clostridium perfringens	2	7.5	-0.88	~ 0.35	unknown
Mycobacteria	4	0.38	0.43	0.19	unknown

The results of the precision analyses for standard bacterial plate count, total coliform, fecal coliform, coliphage, fecal streptococci, and the pathogenic microorganism assayed only from Pleasanton are presented respectively in Tables VI.D-9 through VI.D-14. The mean of |OMD| and the largest OMD value summarize the prediction precision for a data group in terms of the orders of magnitude of the discrepancy. The geometric means of the discrepancy factors F give the average size of the factor of discrepancy between C-B and P. The distribution of the discrepancy factors is described by presenting the percentages of these factors below 2 (i.e., C-B and P within a factor of 2 of each other), below 5, and below 10.

The precision analysis of standard bacterial plate count model predictions is presented in Table VI.D-9 separately for Pleasanton, Deer Creek Lake and Fort Huachuca, and together for all three sites. Satisfactory and very similar precision was found in the standard bacterial plate count model predictions at all three sites. The geometric mean of the discrepancy factors ranged only from 2.64 at Fort Huachuca to 2.89 at Pleasanton, with an average discrepancy of a factor of 2.70 between P and C-B over all 98 data pairs at the three sites. At each site, 43 percent of the (C-B,P) pair values differed from each other by less than a factor of 2. Ninety-five percent of the data pairs at the three sites had a discrepancy factor below 10 (i.e., less than a one order of magnitude discrepancy). Thus, the microbiological dispersion model predicts aerosol concentrations of standard bacterial plate count from unchlorinated and slightly chlorinated wastewater (≤ 0.4 mg/l total chlorine) quite well. The model's predictive ability for standard bacterial plate count appears to be equivalent at Pleasanton, Deer Creek Lake, and Fort Huachuca.

The precision analysis given in Table VI.D-10 for total coliform model predictions shows considerable differences in predictive precision from one site to another. The precision of model predictions of confirmed total coliforms at Pleasanton compares favorably with standard bacterial plate count precision at

Table VI. D-9
ANALYSIS OF THE PRECISION OF STANDARD BACTERIAL PLATE COUNT MODEL PREDICTIONS

	Sites			
	Pleasanton	**Deer Creek Lake**	**Ft. Huachuca**	**All Sites and Methods**
(C-B,P) Pairs with Detectable* Measured Concentrations	7	54	37	98
Mean of |OMD|	0.46	0.43	0.42	0.43
Largest OMD	+0.92	+1.15	+1.23	+1.23
Percentage of Discrepancy Factors:				
Below 2	43%	43%	43%	43%
Below 5	57%	80%	76%	77%
Below 10	100%	93%	97%	95%
Geometric Mean of Discrepancy Factors F	2.89	2.72	2.64	2.70

*Above background (C-B ≥ 0.5B) and detection limit (C ≥ DL) and excluding presumably contaminated samples.

Table VI. D-10

ANALYSIS OF THE PRECISION OF TOTAL COLIFORM MODEL PREDICTIONS

	Assay Methods				All Methods at Unchlorinated Sites
	Confirmed	Presumptive			
		Endo Agar	Endo Broth		
	Pleasanton	Ft. Huachuca	Ft. Huachuca	Deer Creek Lake	
(C-B,P) Pairs with Detectable* Measured Concentrations	8	24	9	8	41
Mean of |OMD|	0.41	0.72	0.65	1.50	0.64
Largest OMD	-1.18	+ 2.37	+ 1.43	+ 2.09	+ 2.37
Percentage of Discrepancy Factors:					
Below 2	50%	21%	33%	0%	29%
Below 5	88%	67%	67%	0%	71%
Below 10	88%	71%	67%	13%	73%
Geometric Mean of Discrepancy Factors F	2.55	5.2	4.5	32	4.4
Total Chlorine in Wastewater (mg/l)	>0.1	"none"	"none"	0.1-0.4	< 0.1

*Above background (C-B ⩾ 0.5B) and detection limit (C > DL) and excluding presumably contaminated samples.

Table VI. D-11
ANALYSIS OF THE PRECISION OF FECAL COLIFORM MODEL PREDICTIONS

	Sites		
	Pleasanton	**Ft. Huachuca**	**All Sites and Methods**
(C-B,P) Pairs with Detectable* Measured Concentrations	5	2	7
Mean of |OMD|	0.39	1.43	0.69
Largest OMD	+0.88	+1.97	+1.97
Percentage of Discrepancy Factors:			
Below 2	60%	0%	43%
Below 5	80%	50%	71%
Below 10	100%	50%	86%
Geometric Mean of Discrepancy Factors F	2.47	27	4.9

*Above background (C-B ≥ 0.5B) and detection limit (C > DL) and excluding presumably contaminated samples.

Table VI. D-12
ANALYSIS OF THE PRECISION OF COLIPHAGE MODEL PREDICTIONS

	Sites		
	Natural	**Seeded f2**	
	Pleasanton	**Ft. Huachuca**	**All Sites and Methods**
(C-B,P) Pairs with Detectable* Measured	5	15	20
Mean of |OMD|	0.38	0.48	0.46
Largest OMD	-0.52	+ 0.98	+ 0.98
Percentage of Discrepancy Factors:			
Below 2	20%	27%	25%
Below 5	100%	73%	80%
Below 10	100%	100%	100%
Geometric Mean of Discrepancy Factors F	2.42	3.04	2.87

*Above background (C-B ≥ 0.5B) and detection limit (C > DL) and excluding presumably contaminated samples.

Pleasanton or any other site (e.g. an F geometric mean of 2.55 for total coliform at Pleasanton versus standard bacterial plate count values of 2.89 at Pleasanton and 2.70 at all sites). The precision of model predictions of presumptive total coliforms at Fort Huachuca is considerably worse, for assays both on Endo agar (F geometric mean = 5.2) and on Endo broth (F geometric mean = 4.5). At Deer Creek Lake, the model predictions of presumptive total coliforms on Endo broth were consistent one-to-two orders of magnitude underestimates of the net measured aerosol concentrations; the geometric mean of the discrepancy factors was 32. These site differences in model predictive ability may be related to the amount of chlorine in the sprayed wastewater (shown at the bottom of Table VI.D-10). Since model underpredictions of about two orders of magnitude for standard bacterial plate count were observed on the runs at Fort Huachuca using highly chlorinated wastewater (see Table VI.D-2), it is plausible to attribute model underpredictions of one-to-two orders of magnitude for the fragile total coliforms at Deer Creek Lake to the slightly chlorinated wastewater (0.1-0.4 mg total chlorine per liter).

As with total coliform, the analyses of fecal coliform (Table VI.D-11), coliphage (Table VI.D-12), and fecal streptococci (Table VI.D-13) show better precision for the model predictions at Pleasanton than at Fort Huachuca, although the distinction for coliphage is slight. The model predictions at Pleasanton for coliphage (F geometric mean = 2.42) and fecal coliform (F geometric mean = 2.47) tended to give precise estimates of the net measured aerosol concentrations. While subject to uncertainty due to the small number of data pairs, the precision analyses of the pathogenic microorganism model predictions in Table VI.D-14 suggest that model predictions of *Clostridium perfringens* and *Pseudomonas* have less precision than do predictions at Pleasanton of the other microorganism groups.

Table VI. D-13
ANALYSIS OF THE PRECISION OF FECAL STREPTOCOCCI
MODEL PREDICTIONS

	Sites		
	Pleasanton	Ft. Huachuca	All Sites and Methods
(C-B,P) Pairs with Detectable* Measured Concentrations	8	2	10
Mean of |OMD|	0.62	0.97	0.69
Largest OMD	-1.33	+ 1.28	-1.33
Percentage of Discrepancy Factors:			
Below 2	25%	0%	20%
Below 5	63%	50%	60%
Below 10	88%	50%	80%
Geometric Mean of Discrepancy Factors F	4.2	9.2	4.9

*Above background (C-B ≥ 0.5B) and detection limit (C > DL) and excluding presumably contaminated samples.

A summary of the precision of microbiological dispersion model predictions using all methods at all sites (excluding the Deer Creek Lake predictions for total coliform because of the probable chlorination effect) is presented in Table VI.D-15. Of the five microorganism groups evaluated at sampling sites in addition to Pleasanton, the most precise model predictions were obtained for standard bacterial plate count and coliphage, for which the discrepancies averaged less than a factor of three. However, the geometric means of the discrepancies averaged less than a factor of five for the other three microorganism groups (total coliform, fecal coliform, and fecal streptococci). Considering the imprecision of microorganism aerosol measurements, the predictions of the microbiological dispersion model may have sufficient precision to replace direct measurement in many applications.

Table VI. D-14
ANALYSIS OF THE PRECISION OF PATHOGENIC MICROORGANISM MODEL PREDICTIONS AT PLEASANTON

	Pseudomonas	*Clostridium Perfringens*	Mycobacteria
(C-B,P) Pairs with Detectable* Measured Concentrations	4	2	4
Mean of |OMD|	0.77	0.88	0.47
Largest OMD	-1.01	-1.45	+ 1.01
Percentage of Discrepancy Factors:			
Below 2	0%	50%	50%
Below 5	25%	50%	75%
Below 10	75%	50%	75%
Geometric Mean of Discrepancy Factors F	5.9	7.5	2.9

*Above background (C-B ⩾ 0.5B) and detection limit (C > DL) and excluding presumably contaminated samples.

Table VI. D-15

SUMMARY OF MODEL PREDICTION PRECISION FOR ALL SITES AND METHODS

Microorganism Group	(C-B,P) Pairs with Detectable Measured Concentrations	Geometric Mean of All Discrepancy Factors F	Percentage of Discrepancy Factors F Below: 2	5	10
Standard Bacterial Plate Count	98	2.7	43%	77%	95%
Coliphage	20	2.9	25%	80%	100%
Mycobacteria*	4	2.9	50%	75%	75%
Total Coliform +	41	4.4	29%	71%	73%
Fecal Coliform	7	4.9	43%	71%	86%
Fecal Streptococci	10	4.9	20%	60%	80%
*Pseudomonas**	4	5.9	0%	25%	75%
*Clostridium Perfringens**	2	7.5	50%	50%	50%

+ Excludes Deer Creek Lake pairs because of probable clorination effect.

*All data pairs are from the Pleasanton sampling program.

VII. DISCUSSION OF MICROBIOLOGICAL DISPERSION MODEL

A. Model Components

1. Aerosolization Efficiency E

It has been reported(66) that aerosolization efficiency depends upon spray nozzle type, spray arc height, spray pressure, and wind velocity. Nozzle type, spray height, and spray pressures are operating conditions that differ from one spray irrigation site to another. Thus, the aerosolization efficiency values given in Table VI.C-2 can be considered characteristic only of the Pleasanton site, and not necessarily characteristic of other spray irrigation sites.

The median aerosolization efficiency obtained for the Rainbird impact sprayers at Pleasanton over the 17 runs during Phase II was 0.33 percent. This agrees very well with the aerosolization efficiencies found for Rainbird impact sprayers at Ft. Huachuca, Arizona (median of 0.29 percent over three runs)(67) at Deer Creek Lake, Ohio (median of 0.47 percent over four runs)(68), and at other sites(69). All of these studies estimated aerosolization efficiency using water-soluble fluorescent dyes and diffusion modeling.

It is clear from Table VI.C-2 that an order-of-magnitude variation in aerosolization efficiency may occur at a given site. The aerosolization efficiency regression equation (5) associates 80 percent of this variation with changes in meteorological conditions. Equation (5) indicates that the aerosolization efficiency at Pleasanton increases with increasing air temperature, increasing wind velocity, and increasing solar radiation. It agrees with the previously identified relationship of aerosolization efficiency to wind velocity(70 (perhaps due to shearing forces), and implies that aerosolization efficiency is also influenced by other meteorological factors that affect the evaporative capability of the air. Fairly high correlations typically occur among solar radiation, air temperature, wind velocity, and relative humidity. Thus it is difficult to identify through regression the precise combination of these meteorological factors that affect evaporative capability. In summary, an order-of-magnitude variation in aerosolization efficiency may occur at a given site, apparently as a result of variation in atmospheric conditions that influence shearing forces, and evaporative capability.

The aerosolization efficiencies for the two dye runs made during Phase I at Pleasanton(71) were 0.6 percent and 0.5 percent. The equation (5) (p. 142) predictions of aerosolization efficiency for these runs' atmospheric conditions were 1.1 percent and 0.9 percent. This verifies our inference (cf. Section VI.C.3) that equation (5) generally predicts the aerosolization efficiency at Pleasanton to within a factor of two.

Equation (5) may be insufficient to predict the aerosolization efficiency at spray irrigation sites other than Pleasanton because aerosolization efficiency depends upon the operating conditions.(72) At some sites such as Ft. Huachuca and Deer Creek Lake the operating conditions were similar enough to warrant use of equation (5). However, at sites with different operating conditions, assuming that the effects of operating conditions are relatively independent of the effects of meteorological conditions, reasonable aerosolization efficiency estimates can still be obtained. A previous study of spray equipment and operating conditions(73), or a limited dye aerosol sampling program at a site, can be utilized to estimate the site aerosolization efficiency under one set of meteorological conditions. The constant in equation (5) can then be adjusted so that aerosolization efficiencies for a site can be predicted under other meteorological conditions.

It should be noted that the solar radiation measurements at Pleasanton were made with a vertical Belfort Pyrheliograph, which is a short wave instrument. Solar radiation measurements vary considerably depending upon the type of recording instrument used. Thus in making aerosolization efficiency predictions using equation (5), the solar radiation, r, used in the equation should be from a vertical short wave instrument (e.g., vertical Eppley).

2. Impact Factor I

The initial, supposedly rapid, microbiological die-off of wastewater aerosols is seldom quantified separately from the aerosolization efficiency effect in the literature. Results reported by Sorber *et al*(74) can be converted to a net impact factor I = 0.12, for total aerobic bacteria over eight aerosol runs using Andersen samplers. Since this is approximately the 25th percentile of the standard bacterial plate count I distribution in Table VI.C-6, satisfactory agreement is indicated.

The individual impact factor estimates for a microorganism group during a run contain considerable uncertainty. With the exception of total coliform, the majority of individual impact factor estimates were less than twice their standard errors. Frequently, in fact, the standard error exceeded the impact factor estimate. This uncertainty should be kept in mind when interpreting the empirical distributions of impact factors given in Table VI.C-6. However, it is likely that both the central tendency and dispersion of the true I distributions are well represented by the I estimate distributions.

The middle ranges (i.e., from the 25th to the 75th percentile) of the impact factor distributions given in Table VI.C-6 suggest how well various microorganism groups survive the initial impact of aerosolization. The viability of the putative wastewater indicator microorganism groups (fecal coliform, total coliform, standard bacterial plate count, and coliphage) was substantially reduced through aerosol impact. Generally only 6 to 60 percent of these microorganisms in the sprayed wastewater survived the initial seconds of aerosolization.

The pathogenic bacteria and enteroviruses studied appear to survive aerosol formation and initial contact with the atmospheric environment much better than the usual indicator organisms. The impact factor estimates obtained at Pleasanton for *Pseudomonas*, fecal streptococci, *Clostridium perfringens*, mycobacteria, and the enteroviruses were unexpectedly high, usually in excess of 1.0. A discussion is given in Section VII.C.1 of possible explanations for these large impact values, which superficially suggest survival above 100 percent.

The impact factor values for most of the microorganisms studied exhibited variation over several orders of magnitude between their 10th and 90th percentiles. The literature generally implicates ultraviolet solar radiation as a factor in microorganism die-off. There is also some evidence(75) that aerosolized bacteria are reduced mainly at middle relative humidities (40-60 percent), and that high temperatures (>27°C) may also reduce microbiological aerosols. Thus, variation in atmospheric conditions is suggested as a probable cause of the variation in impact factor values within a microorganism group.

The preliminary analysis (see Appendix G), of the association of impact factor values with pertinent meteorological variables during the Pre-Fair runs, is also relevant. This analysis suggests that the impact factors for total coliform, fecal coliform, and coliphage are reduced at low and middle relative humidities. The total coliform and coliphage impact factors appear to be further reduced for the combination of high solar radiation and high wind velocity, and for temperature difference between wastewater and air. The standard bacterial plate count impact factor may be lowered with strong solar radiation. Reductions in the impact factors for the pathogenic bacteria (fecal streptococci, *Pseudomonas*, and *Clostridium perfringens*) seem to occur primarily for the combination of high wind velocities with low relative humidities. Because there were fairly high correlations among solar radiation, temperature, relative humidity, and wind velocity during Pre-Fair runs, it is not clear whether the identified meteorological factor or a highly correlated alternative was actually associated with an impact factor reduction.

As the model prediction examples illustrate, selection of an appropriate impact factor value is a key step in making a model prediction for Pleasanton or elsewhere. To maximize predictive ability, selection of the I value should be based on the relationship of impact factor estimates for a microorganism group in Table VI.C-4 to the relevant atmospheric conditions occurring during their respective aerosol runs.

Such a direct analysis is needed to identify the nature of the relationship and to establish its strength. Unfortunately, the proper technique, a biased multiple regression analysis, was beyond the scope and time frame of the current research effort. Hence, this analysis was not conducted.

Lacking this impact factor regression relationship, judicious application of the qualitative results of the preliminary analysis of the Pre-Fair data must be substituted. These results provide some basis for predicting whether the impact factor for a microorganism group under a specific set of atmospheric conditions is likely to be below, near, or above the median value obtained at Pleasanton. Thus, these associations of impact factors with atmospheric conditions can be used in making microbiological dispersion model predictions to select an appropriate percentile, presented in Table VI.C-6 as the microorganism I value. For making model predictions, selecting I values below the 25th percentile or above the 75th percentile is not recommended, both because of the uncertainty in the I estimates and because of the weak qualitative associations with atmospheric conditions. Suppose, for example, that a prediction of the total coliform concentration is to be made for a hot, sunny, dry, and windy summer afternoon, which might be the most hostile impact factor case. The 40th percentile $I = .13$ might be used to obtain a typical total coliform aerosol concentration, while the 25th percentile $I = .06$ might be appropriate for calculating a "best case" aerosol concentration. Conversely, under very favorable atmospheric conditions, the 60th percentile $I = .23$ might yield a typical total coliform aerosol concentration, while the 75th percentile $I = .55$ might give a "worst case" aerosol concentration.

3. Viability Decay Rate

The measurement of a sizable reduction in the microbiological aerosol concentration over a large aerosol age (distance) span downwind from the wastewater source is required to calculate an accurate viability decay rate. In field studies, this requirement dictates the simultaneous operation of several high-volume aerosol samplers, which are expensive and difficult to operate(76). For this reason, viability decay rates based on field studies have seldom been reported in the literature. A net viability decay rate equivalent to $\lambda = —0.06\ s^{-1}$ was calculated for total aerobic bacteria over eight aerosol runs by Sorber, *et al*(77). Since this value is around the 15th percentile of the standard bacterial plate count λ distribution in Table VI.C-10, it suggests slightly more rapid decay than do the viability decay rate values presented herein.

The individual viability decay rate estimates in Table VI.C-7 contain substantial uncertainty. Both the relative magnitude of the standard errors of the λ estimates and the frequency of non-negative decay rate estimates (denoted as $\lambda = X$) attest to this uncertainty in the individual estimates. These uncertainties, which reflect state-of-the-art sampling and analytical limitations, should be recognized in interpreting the λ distributions presented in Table VI.C-10.

For hardy microorganisms experiencing slow viability decay, very large sampling distances and very low detection limits are needed to quantify the viability decay rate. Because of their relatively low wastewater concentrations at Pleasanton, the hardy pathogenic bacteria were infrequently detected in the aerosol samples taken far downwind of the spray line. For this reason, only values in the lower (rapid decay) portions of the viability decay rate distributions of the pathogenic bacteria could be quantified in Table VI.C-10.

For all microorganism groups, the upper portion of the λ distribution, which represents the slower die-off rates, cannot be quantified based on the Pleasanton study. Table VI.C-10 suggests that $—0.01s^{-1}$ to $—0.02s^{-1}$ was the lowest viability decay rate which could be detected at Pleasanton. For the hardier and partially analyzed microorganisms, such as mycobacteria, *Pseudomonas*, and fecal streptococci, perhaps $—0.06s^{-1}$ was the lowest detectable viability decay rate.

Values for the unquantified percentiles in Table VI.C-10 can be estimated by interpolating between the highest quantified percentile value and the logical upper limit, $\lambda = 0$ (no viability decay). This interpolation procedure was employed in the prediction examples to estimate the 40th, 60th and 75th percentile λ values for mycobacteria, enteroviruses, and fecal streptococci in Tables VI.C-11, 12, and 13. Even at the sizable aerosol ages of these examples, the exponential die-off factor, $e^{\lambda a}$, for these slowly decaying microorganisms makes only a slight reduction in the predicted aerosol concentration. Thus, the added uncertainty in P, introduced by using an interpolated value for the viability decay rate, is slight.

Perusal of Table VI.C-10 indicates that the indicator microorganism groups, especially total coliform and fecal coliform, experienced more consistent and rapid die-off with aerosol age than did the pathogenic bacteria evaluated. Based on their viability decay rates, the microorganism groups seem to fall into three categories. Total coliform and fecal coliform were similar in that they exhibited the most rapid decay and their decay rates could most frequently be estimated. Furthermore, the viability decay rate estimates for total and fecal coliform were also more reliable than for the other microorganism groups. Viability decay appeared to occur on about 50 percent of the runs for a second category of microorganisms (coliphage, *Clostridium perfringens*, and standard pacterial plate count); their rates of decay were also slower than the coliform decay rates. Decay with aerosol age could seldom be detected for the third category (mycobacteria, *Pseudomonas*, and fecal streptococci).

The viability decay rate distributions also reflect substantial variation in microbiological die-off with aerosol age from one run to another. Die-off that increases with high solar radiation, low-to-middle relative humidity, and high temperature has often been suggested(78,79,80). Thus, the different meteorological conditions during runs are presumed to cause the variation in die-off rates. Our preliminary analysis of the association of viability decay rates with meteorological variables, based on the Pre-Fair Pleasanton data, confirms these general relationships. For most microorganism groups, rapid viability decay does seem to be associated with summer daytime atmospheric conditions as identified through meteorological variables such as high temperature, middle relative humidities and high solar radiation. However, there is also much variation in the viability decay rates of a microorganism group under apparently similar sets of atmospheric conditions.

Selecting a proper decay rate value is crucial to making an accurate model prediction at substantial distances from the microbiological aerosol source. A direct analysis of the relationship of microorganism λ estimates to atmospheric conditions is needed, both to discriminate between the "rapid decay" and "insignificant decay" sets of atmospheric conditions, and to develop a regression relationship to predict the decay rate for the rapid decay conditions. Because of its complexity, such an analysis was beyond the scope and time frame of the present research effort.

Lacking such discrimination and regression relationships, the only basis for selecting a decay rate λ for use in model prediction are the general findings discussed above. Consideration of general atmospheric conditions on a daytime-nighttime scale is recommended as the basis for selecting a viability decay rate value for any microorganism group from the Table VI.C-10 distributions. Because the actual relationships of atmospheric conditions to decay rates are unknown, it is suggested that the decay rates used in predictive model calculations be restricted to the middle range (i.e., from the 25th to the 75th percentiles). Perhaps the 40th percentile might be taken as a typical summer daytime value, while the 60th percentile might reflect typical nighttime conditions.

8. Validity of the Model and its Predictions

The preliminary assessment in Section VI.C.7 of factors affecting Pre-Fair microbiological aerosol levels provided justification for establishing the multiplicative form of the microbiological dispersion model, as given in equation (3). The reasonable physical interpretations that can be given to each model factor and parameter enhance the usefulness of the equation (3) form for expressing the microbiological dispersion model.

In using the microbiological dispersion model for predicting microorganism aerosol concentrations from spray irrigation systems, three major assumptions are made: that the multiplicative form of the model is valid; that microorganism die-off depends only on factors such as atmospheric conditions which are independent of the spray site; and that the sampling, shipping, and assay methods of the Pleasanton study are employed. If these model assumptions are valid, the microbiological dispersion model should be applicable to any spray irrigation site over the range of meteorological conditions occurring during the Pleasanton aerosol sampling runs. The extremes of meteorological conditions on the Pleasanton aerosol runs (see Table VI.B-1) are summarized in Table VII.B-1.

Table VII.B-1
METEOROLOGICAL CONDITIONS OF PLEASANTON AEROSOL RUNS

	Range of Values	
	Low	High
Dry Aerosol Runs		
Temperature, °C	7	34
Solar Radiation, W/m²	<20	930
Relative Humidity, %	5	80
Wind velocity, m/s	1.2	8.5
Microbiological Aerosol Runs		
Temperature, °C	8	37
Solar Radiation, W/m²	<20	900
Relative Humidity, %	5	86
Wind Velocity, m/s	0.5	7.2

At the present state of model development, predictions of the model have an important shortcoming. The procedure suggested above for selecting the I and λ parameter percentiles as a function of atmospheric conditions does not have adequate statistical justification. As discussed above, the existing Pleasanton data have not been analyzed to determine the relationships of the individual I and λ estimates for each microorganism group to the aerosol run atmospheric conditions. Sophisticated regression techniques, such as biased regression, appear necessary to elucidate such relationships. The complexity of this analysis precluded its conduct within the scope and time frame of this research effort. However, since this analysis is necessary to achieve the full potential usefulness of the microbiological dispersion model, it is recommended as a priority research area.

The effect of atmospheric conditions on an individual model parameter (D, E, I, or λ) is sometimes stronger that its net effect on the predicted concentration P. This happens because the atmospheric condition effects on D, E, I, and λ tend to vary in opposite directions that partially cancel out in the resulting prediction. Comparison of the daytime and nighttime cases in Table VI.C-13 illustrates this characteristic. While the summer midday atmospheric conditions reduce the microbiological model factors I and $e^{\lambda a}$ and the diffusion concentration D well below their nighttime levels, they simultaneously elevate the aerosolization efficiency E. Thus, when projecting the effect of a change in a single meteorological variable on the downwind microbiological aerosol concentration, its influence on all of the model parameters should be taken into account.

The accuracy and precision of the predictions of the microbiological dispersion model were examined in the model evaluation. Enough field data were available to provide a thorough model evaluation at realistic field sampling distances (<200 meters from the source boundary) under a variety of sampling and analytical procedures for standard bacterial plate count, and useful evaluations for total coliform and coliphage. However, the predictive ability of the model remains untested for fecal coliform, fecal streptococci, *Pseudomonas*, *Clostridium perfringens*, and mycobacteria at sites other than Pleasanton.

The predictions of the microbiological dispersion model were quite accurate over the field data evaluated. The predictions tended to be slightly less than the net measured aerosol concentrations, averaging 64 percent of the net measured value for standard bacterial plate count, and 73 percent for both total coliform and coliphage (see Table VI.D-8). No significant bias could be detected for total coliform and coliphage, but the prediction underestimates for standard bacterial plate count and fecal coliform do indicate a slight bias in their predictions.

The microbiological dispersion model predictions have satisfactory precision, considering the sizable sampling and analytical uncertainty present in microorganism aerosol concentration determinations. The preponderance of the model predictions (e.g. 95 percent of standard bacterial plate count predictions, 73 percent of total coliform predictions, and 100 percent of coliphage predictions) were within one order of magnitude of the net measured values (see Table VII.D-15). Most model predictions (e.g., 77 percent for standard bacterial plate count, 71 percent for total coliform, and 80 percent for coliphage) were within a factor of five of their net measured value. The geometric mean of the discrepancy factors was less than three for standard bacterial plate count, coliphage, and mycobacteria and less than five for total coliform, fecal coliform, and fecal streptococci.

It should be recognized that the model accuracy and precision statistics were based largely on field data obtained within 50 meters of the edge of the wetted spray area. Over these distances, the viability decay model factor $e^{\lambda a}$ has little effect on the computed model prediction P. Thus, the model evaluation has primarily evaluated the appropriateness of the E and I model parameters, with minimal attention given to λ. Since the viability decay rates obtained at Pleasanton varied widely, it is to be expected that both the accuracy and precision of the model predictions will deteriorate with distance from the wastewater aerosol source.

When the wastewater that is aerosolized contains residual levels of total chlorine, the microbiological dispersion model tends to underpredict the net measured aerosol concentration. Table VI.D-2 suggests underprediction of standard bacterial plate count aerosol concentrations by one and one half to three orders of magnitude at a total residual chlorine concentration of 6 mg/l in the sprayed wastewater. The Deer Creek Lake wastewater that was sprayed contained total residual chlorine concentrations in the range of 0.1 mg/l to 0.4 mg/l. The model predictions of presumptive total coliforms on Endo broth and of standard bacterial plate count were both below the net measured aerosol concentrations at Deer Creek Lake, by one to two orders of magnitude for total coliform (Table VI.D-10), and by nearly a factor of two for standard bacterial plate count (Table VI.D-3). The degree of model underprediction for chlorinated wastewater aerosols appears to depend both on the extent of residual chlorination and on the fragility of the microorganism group. Unless sufficient data are available to adjust for this chlorination effect, the microbiological dispersion model should not be used to predict microorganism aerosol concentrations of sprayed wastewater containing residual chlorine.

Considering the imprecision and cost of measuring microorganism aerosol concentrations by field sampling, the predictions of the microbiological dispersion model do appear to be a preferable alternative when the sprayed wastewater does not contain residual chlorine.

C. Microbiological Inferences Derived from the Model

1. Interpretation of Impact Factors Exceeding One

Frequent impact factor values exceeding 1.0 were not anticipated for any microorganism group. Occasional I values above 1.0 are to be expected based on the large I standard errors presented in Table VI.C-4. However, about 50 percent of the values obtained as impact factor estimates for fecal streptococci, *Clostridium perfringens* and mycobacteria exceeded 1.0. Nearly all of the enterovirus and *Pseudomonas* impact estimates exceeded this value. Thus, impact factors larger than one apparently characterize these pathogens under many atmospheric conditions with the measurement methodologies employed at Pleasanton.

The facile interpretation of the I values exceeding 1.0 is that substantial net growth rather than die-off of the microorganisms occurred in the hostile aerosol environment during the initial seconds from aerosol formation to sampling at 50 meters downwind. However, this facile interpretation is inconsistent with known microbiological behavior. Thus, one or several more subtle phenomena must be responsible for these high observed I values.

Five possible explanations for the consistent pathogen I values above 1.0 are offered:

- *Survival Hypotheses*. After aerosol sample collection, microorganisms may have survived in the supportive BHI collection fluid at undiminished concentrations over the typical 16- to 24-hour holding time required for sample storage and shipment to the analytical laboratory. However, the survival of human pathogens in the wastewater samples which provide the baseline for comparison with the aerosol sampling over the same holding time may have been reduced because the wastewater presents a relatively hostile environment. The preliminary liquid collection media study conducted in the laboratory showed that, when poliovirus 1 and f2 bacteriophage were inoculated in wastewater, slight reductions in concentration occurred after 24 hours at the holding temperature of 4°C. However, in the BHI medium, stable levels of seeded pathogenic bacteria, poliovirus, and bacteriophage were maintained for several days at 4°C. Thus, at least for coliphage and the enteroviruses, a slight elevation (probably less than a factor of two) of the impact factor might be attributable to differential survival in the wastewater and aerosol collection media.
- *Masking Hypothesis*. The assay procedures may have consistently underestimated the wastewater concentrations of the pathogens due to the masking effect of chemical constituents or of the numerous other microorganisms present in the wastewater. Conversely, the assay procedures may have more accurately estimated the pathogen aerosol concentrations, because of the lower bacterial concentrations present in BHI collection medium, the selective decimation of the masking bacteria in the aerosol state, or the selective exclusion of inhibitory chemicals through aerosolization.
- *Mechanical Splitting Hypothesis*. Microorganisms that tend to exist in grouped form in the wastewater (e.g., the long chains of fecal streptococci and the clumps of mycobacteria aggregates with wastewater solids) may have been mechanically split into individual viable organisms prior to the aerosol assay. The potential for mechanical splitting exists both during aerosolization, through impact and shear forces at the spray head, during collection, through the rapid recirculation of the BHI fluid within the high volume aerosol sampler.
- *Regrowth Hypothesis*. Regrowth of aerosol-sampled pathogenic microorganisms in the supportive BHI medium could occur under opportune circumstances. Aerosol sample regrowth would be much more rapid than the corresponding regrowth of these microorganisms in the wastewater environment. An opportunity for regrowth of pathogenic bacteria did occur occasionally when the sample shipping temperature rose higher than the 4°C specified in the sampling protocol. However this hypothesis is not valid for enteroviruses.
- *Aerosolization Efficiency Hypothesis*. The aerosolization efficiency E may have frequently been underestimated. If the proportion of sprayed microorganisms that were aerosolized exceeded the proportion of fluorescent dye aerosolized because the dye is not an adequate physical model of microorganism aerosolization, E would have consistently been underestimated. In addition, occasional underestimation of E due to equation (5) uncertainty is also expected. Given the equation (5) standard error of 0.194, the predicted E is expected to be low by at least a factor of two on 7 percent of the run estimates. Underestimation of E for either reason will result in a compensating overestimation of the impact factor I values for all microorganism groups for the affected runs.

The available evidence suggests that the phenomena represented by all five hypotheses may have had an effect on some of the impact factors calculated from the Pleasanton data. The survival hypothesis may always be operative in wastewater assay, but the collection media study data indicate that its magnitude is insufficient to alone account for the large impact factor estimates. The occurrence of masking in the wastewater assay is also quite probable; presumably the size of the masking effect could vary considerably from one sample to another, depending on the concentrations of the masking microorganisms or chemicals that may be present. Mechanical splitting is a likely mechanism of variable magnitude for the microorganisms that persist in grouped form. Except for enteroviruses, the regrowth hypothesis is also plausible when the Pleasanton sampling and shipping protocols were violated. However, all detected violations were carefully noted and their occurrence was too infrequent to explain very many of the high I values. For example, the pathogen assay laboratory received only 3 of the 55 microbiological run sample shipments at elevated temperatures (8°C to 9°C). Occasional underestimation of E due to equation (5) uncertainty did occur, but also with insufficient frequency. Biased underestimation of E, because dye is an inadequate physical model of aerosolization, is plausible, but unsubstantiated. In summary, the survival, masking, and mechanical splitting hypotheses appear to be the most likely explanations of consistently obtaining impact factors above 1.0.

Regardless of which hypotheses are correct, the higher than expected impact factor estimates apparently do reflect real phenomena associated with the current state-of-the-art for wastewater and aerosol sampling and assay for pathogens. Therefore, to satisfy the third model assumption, the high impact factor values presented in Table VI.C-4 should be used without adjustment when predicting pathogen aerosol concentrations with the microbiological dispersion model.

2. Relative Aerosol Survival Hardiness of Microorganism Groups

Comparison of the microorganism groups, with respect to their impact factor values and their viability decay rates, provides an indication of the relative survivability of these groups through the wastewater aerosolization process. A relative hardiness measure was constructed as the sum of separate rankings for initial survival (the median impact factor in Table VI.C-6) and for survival with age [the percentage of very low (unquantified or below $0.01s^{-1}$) decay rates] for each microorganism. The resultant ranking of microorganism groups is presented in Table VII.C-1, with microorganisms having a similar hardiness ranking being clustered together.

It can be inferred from Table VII.C-1 that the commonly used indicators of wastewater microorganisms (total coliform, fecal coliform, coliphage, and standard bacterial plate count) do not survive wastewater aerosolization nearly as well as do the pathogens studied. The evaluated pathogenic bacteria and enteroviruses both better survive the initial shock of aerosolization and more frequently resist aerosol age decay. Therefore, the common "microbiological wastewater indicators", especially total coliform and fecal coliform, are actually very poor indicators of the pathogenic aerosol hazard posed by wastewater spray irrigation. Fecal streptococci appear to be a more acceptable wastewater aerosol indicator. Fecal streptococci are generally present in the wastewater, are readily assayed, and survive wastewater aerosolization well.

D. Model Applications

The microbiological dispersion model should prove valuable in many applications, especially after development of a reliable procedure for selection of the I and λ parameters, and evaluation of model predictions using this selection procedure. The Pleasanton sampling program has demonstrated that, with present microbiological aerosol sampling and assay methods, it is generally impractical to sample wastewater aerosols for microorganisms beyond 100 or 200 meters from their source. Thus, a reliable modeling technique, such as the microbiological dispersion model, is essential to estimate the level of human exposure to pathogens from wastewater aerosols. The microbiological dispersion model could be used to calculate the pathogen exposure levels of plant workers and neighboring residents at existing and candidate spray irrigation sites(81) as part of an evaluation of the potential public health risk. With limited aerosol sampling data, the microbiological dispersion model could also be used to calculate distant downwind concentrations emanating from other microbiological aerosol sources, such as the aeration basins of sewage treatment plants and cooling towers that reuse municipal wastewater.

Table VII.C-1

AEROSOL SURVIVAL HARDINESS OF MICROORGANISM GROUPS

Microorganism Group	Initial Survival Median Impact Factor Value (I)	Survival with Age Percentage of Runs with Low Decay Rate ($\lambda = X$ or $\lambda > -0.01 s^{-1}$)
Total Coliform	0.16	32%
Fecal Coliform	0.13	38%
Coliphage	0.34	49%
Std. Bacterial Plate Count	0.21	67%
Clostridium perfringens	1.2	55%
Mycobacteria	0.89	88%
Fecal Streptococci	1.7	77%
Pseudomonas	14	77%
Enteroviruses	~ 40*	——

*Based on only two special virus aerosol runs

APPENDIX A
MONTHLY ANALYTICAL DATA SHEETS FOR CITY OF PLEASANTON SEWAGE TREATMENT PLANT

MAY—JULY, 1976
DECEMBER, 1976
FEBRUARY—APRIL, 1977

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PLEASANTON WATER [illegible] Month of MAY 19[illegible]

Monthly ANALYTICAL DATA SHEET No. 1

DATE	DAY	SAMPLING HOURS	5 DAY B.O.D. mg/L				SUS. SOLIDS mg/L				TOTAL SOLIDS				TOTAL DISSOLVED SOL.			
			RAW	PRIM.	SEC. EFFL.	OXID. POND No. II EFFL.	RAW	PRIM.	SEC. EFFL.	OXID. POND No. II EFFL.	RAW	PRIM.	SEC. EFFL.	OXID. POND No. II EFFL.	RAW	PRIM.	SEC. EFFL.	OXID. POND No. II EFFL.
1																		
2																		
3																		
4	Tu	24	298/273	219/255	28/36	—	311/[illegible]	126/135	36/32	—	906	682	579	—	612	547	547	—
5																		
6																		
7																		
8																		
9																		
10																		
11	Tu	24	210/243	145/158	26/22	—	305/320	163/150	40/[illegible]	—	883	748	610	—	563	598	576	—
12	W	24	202/210	148/173	28/37	—	365/300	108/91	36/15	—	851	651	606	—	531	560	591	—
13																		
14																		
15																		
16																		
17																		
18	Tu	24	190/171	133/137	35/27	—	362/318	144/192	62/29	—	912	749	650	—	[illegible]	557	621	—
19	W	24	215/194	—	22/22	—	322/250	—	27/26	—	868	—	602	—	618	—	576	—
20																		
21																		
22																		
23																		
24																		
25	Tu	24	228/183	155/152	23/20	—	370/362	99/134	36/38	—	—	718	568	—	—	584	530	—
26																		
27	Th	24	230/303	144/131	21/23	10	314/272	114/160	26/30	15	917	698	638	631	639	538	608	616
28																		
29																		
30																		
31																		
TOTAL			1578/1477	1044/1007	183/187	10	2358/2114	754/862	263/204	15	5337	4256	4253	631	3615	3324	4049	616
Avg.			225/211	135/168	26/27	10	337/302	126/144	38/29	15	890	709	608	631	611	564	578	616
Max.			298/273	219/255	35/37	10	370/362	163/192	62/38	15	917	749	650	631	639	598	621	61
Min.			190/171	133/131	21/20	10	305/278	99/91	26/15	15	851	651	568	631	531	538	530	6

[illegible]

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Month of May 1976

Month: Analytical Data Sheet N. 2

			Settleable Sol. ml/L				Hydrogen Ion pH				C.O.D. mg/L				L.A.S. mg/L	Cl2 mg/L	[illegible]	
Date	Day	Sampling hours	Raw	Prim.	Secondary	Oxid. Pond II	Raw	Prim.	Secondary	Oxid. Pond II	Raw	Prim.	Secondary	Oxid. Pond II	Oxid. Pond II	Secondary	Raw	Secondary
1																		
2																		
3																		
4	Tu	24	14.0	0.8	<0.1	—	8.2	7.8	8.0	—						<0.1		
5																		
6																		
2																		
8																		
9																		
10																		
11	Tu	24	13.0	1.3	0.1	—	8.0	7.6	7.8	—						<0.1		
12	W	24	13.0	0.4	<0.1	—	8.9	8.6	8.3	—	--	—	120	—		<0.1		
13																		
14																		
15																		
16																		
17																		
18	Tu	24	11.5	0.2	<0.1	—	8.8	8.0	8.1	—						<0.1		
19	W	24	8.5	—	<0.1	—	8.7	—	8.1	—	—	—	80	—		<0.1		
20																		
21																		
22																		
23																		
24																		
25	Tu	24	15.0	0.1	<0.1	—	8.3	8.2	8.6	—	573	—	78	—		<0.1		
26																		
27	Th	24	13.5	0.1	<0.1	<0.1	8.5	8.1	8.2	8.3					0.86	<0.1		
28																		
29																		
30																		
31																		
Total			88.5	2.9	<0.1	<0.1	59.4	48.3	57.1	8.3	573		278		0.86	<0.1		
Avg.			12.6	0.5	<0.1	<0.1	8.5	8.1	8.2	8.3	573		93		0.86	<0.1		
High			15.0	1.3	<0.1	<0.1	8.9	8.6	8.6	8.3	573		120		0.86	<0.1		
Low			8.5	0.1	<0.1	<0.1	8.0	7.6	7.8	8.3	573		78		0.86	<0.1		

Monthly Analytical Data Sheet [illegible] 3

Date	Day	Avg. of Daily Hourly Grabs	Total Sulfide mg/l				Dissolved Sulfide mg/l				Dissolved Oxygen mg/l				Hydrogen Ion pH			
			Raw Infl.	Prim Effl.	Filter Effl.	Sec. Effl.	Raw Infl.	Prim. Effl.	Filter Effl.	Sec. Effl.	Raw Infl.	Prim. Effl.	Filter Effl.	Sec. Effl.	Raw Infl.	Prim. Effl.	Filter Effl.	Sec. Effl.
1	Sa	4	0.33	0.10	0.30	<0.05	0.20	<0.05	<0.05	<0.05	2.3	2.5	0.8	0.3	9.1	9.0	8.0	7.9
2	Su	4	0.48	0.13	0.23	<0.05	0.30	0.08	<0.05	<0.05	2.4	2.1	0.4	0.2	9.2	8.9	8.0	8.0
3	M	6	0.90	0.20	0.22	0.12	0.45	<0.05	<0.05	0.06	3.5	2.3	0.6	0.3	9.0	9.0	8.2	8.1
4	Tu	6	0.72	<0.05	0.28	0.17	0.15	<0.05	<0.05	0.13	3.8	2.1	0.5	0.4	8.6	8.8	8.0	8.0
5	W	6	0.72	0.08	0.22	0.13	0.32	<0.05	<0.05	<0.05	3.0	3.1	0.9	0.8	9.0	9.1	8.2	8.1
6	Th	6	0.35	<0.05	0.27	<0.05	0.17	<0.05	<0.05	<0.05	2.5	2.9	1.1	0.4	9.6	9.2	8.3	8.1
7	F	6	0.47	<0.05	0.30	<0.05	0.22	<0.05	<0.05	<0.05	2.5	3.3	1.7	0.3	9.4	9.2	8.4	8.2
8	Sa	3	0.70	0.13	0.33	<0.05	0.23	0.10	<0.05	<0.05	3.5	4.0	1.1	0.5	9.4	9.5	8.4	8.1
9	Su	4	0.30	0.08	0.23	<0.05	0.15	<0.05	<0.05	<0.05	2.8	3.7	1.3	0.6	9.1	9.0	8.2	8.1
10	M	6	0.43	0.15	0.28	<0.05	0.20	<0.05	<0.05	<0.05	2.3	2.9	0.9	0.1	9.2	9.0	8.1	8.1
11	Tu	6	0.40	<0.05	0.37	<0.05	0.17	<0.05	<0.05	<0.05	2.2	3.2	0.9	0.1	9.5	9.3	8.1	8.1
12	W	6	0.54	<0.05	0.34	<0.05	0.18	<0.05	<0.05	<0.05	1.5	3.6	1.4	0.3	9.2	9.3	8.4	8.2
13	Th	6	0.45	<0.05	0.20	<0.05	0.28	<0.05	<0.05	<0.05	3.0	3.1	1.5	0.5	9.1	9.2	8.3	8.3
14	F	6	—	—	0.20	<0.05	—	—	<0.05	<0.05	—	—	—	0.6	8.6	—	—	—
15	Sa	5	—	—	0.14	<0.05	—	—	<0.05	<0.05	—	—	—	0.7	8.7	—	—	—
16	Su	6	—	—	0.25	0.05	—	—	<0.05	<0.05	—	—	—	0.9	8.8	—	—	—
17	M	8	—	—	1.04	0.11	—	—	<0.05	<0.05	—	—	—	0.8	8.9	—	—	—
18	Tu	8	—	—	0.83	0.06	—	—	<0.05	<0.05	—	—	—	1.0	9.0	—	—	—
19	W	8	—	—	0.55	<0.05	—	—	<0.05	<0.05	—	—	—	0.6	8.8	—	—	—
20	Th	8	—	—	0.40	<0.05	—	—	<0.05	<0.05	—	—	—	0.8	8.9	—	—	—
21	F	8	—	—	0.40	<0.05	—	—	<0.05	<0.05	—	—	—	1.4	8.9	—	—	—
22	Sa	6	—	—	0.24	<0.05	—	—	<0.05	<0.05	—	—	—	1.1	8.8	—	—	—
23	Su	5	—	—	0.48	<0.05	—	—	<0.05	<0.05	—	—	—	1.3	8.8	—	—	—
24	M	8	—	—	0.25	<0.05	—	—	<0.05	<0.05	—	—	—	0.5	8.9	—	—	—
25	Tu	8	—	—	0.30	<0.05	—	—	<0.05	<0.05	—	—	—	1.2	8.9	—	—	—
26	W	8	—	—	0.21	<0.05	—	—	<0.05	<0.05	—	—	—	0.7	8.9	—	—	—
27	[illegible]	8	—	—	0.26	<0.05	—	—	<0.05	<0.05	—	—	—	0.7	8.9	—	—	—
28	[illegible]	8	—	—	0.29	<0.05	—	—	<0.05	<0.05	—	—	—	0.7	9.1	—	—	—
29	[illegible]	6	—	—	—	—	—	—	—	—	—	—	—	0.7	9.1	—	—	—
30	Su	6	—	—	—	—	—	—	—	—	—	—	—	0.7	8.9	—	—	—
31	M	7	—	—	—	—	—	—	—	—	—	—	—	0.7	8.9	—	—	—
TOTAL			6.79	0.87	9.41	0.64	3.08	0.18	<0.05	0.19	35.3	38.8	13.1	19.9	279.2	118.5	106.6	105.3
AVG.			0.52	0.07	0.34	0.02	0.24	0.01	<0.05	<0.05	2.7	3.0	1.0	0.6	9.0	9.1	8.2	8.1
MAX.			0.90	0.20	1.04	0.17	0.45	0.10	<0.05	0.13	3.8	4.0	1.7	1.4	9.6	9.5	8.4	8.3
MIN.			0.30	<0.05	0.14	<0.05	0.15	<0.05	<0.05	<0.05	1.5	2.1	0.4	0.1	8.6	8.8	8.0	7.9

PLEASANTON WATER POLLUTION [illegible]

Month of MAY 1976

Monthly Analytical Data Sheet No. 4
Activated Sludge

Date	Day	Mixed Liquor Bio-Sump No. I				Mixed Liquor Bio-Sump No. II				Return Activated Sludge Aeration Tank					Per Cent of Return	Avg. Plant Flow M.G.D.
		pH	Sus. Sol.	Set Sol.	S.V.I.	pH	Sus. Sol.	Set. Sol.	S.V.I.	Sus. Sol.	D.O.	% Ash	Aerated Waste Gal/Day	Sec. Return M.G.D.		
1	Sa					8.15	2385	95	40	7625	3.6	—	17800	0.9504	74	1.29
2	Su					8.00	2340	100	43	7220	2.9	—	16900	0.9504	73	1.30
3	M					8.00	2447	107	48	7965	3.7	—	17000	0.9504	68	1.40
4	Tu				—	7.80	2830	118	42	8683	2.0	22	20300	0.9504	72	1.31
5	W					8.00	2537	115	47	8302	3.4	—	20500	0.9504	73	1.30
6	Th					8.00	2255	108	48	7660	3.3	—	20500	0.9504	73	1.30
7	F					8.00	1987	100	51	7030	3.4	—	20700	0.9504	69	1.38
8	Sa					7.90	2000	90	45	7510	3.5	—	20500	0.9504	74	1.28
9	Su					7.90	1802	87	50	6847	3.8	—	20400	0.9504	75	1.26
10	M	8.20	1963	112	56	7.90	2197	105	49	7153	3.3		20600	0.9504	70	1.36
11	Tu	8.60	2123	103	49	8.10	2087	103	50	6800	2.0	22	20600	0.9504	71	1.33
12	W	8.40	1850	105	58	8.20	2087	98	49	7107	2.4	—	15000	0.9504	71	1.33
13	Th	8.45	2450	118	51	8.35	2287	113	51	7570	2.2		11500	0.9504	72	1.31
14	F	8.20	1645	95	58	7.90	1595	93	58	5780	3.1	—	11500	0.9504	70	1.36
15	Sa	8.20	2410	113	48	8.00	2357	112	49	6713	2.8	—	12200	0.9504	73	1.30
16	Su	8.70	5030	270	54	8.20	5620	270	48	16190	1.4	—	12400	0.9504	73	1.30
17	M	8.60	4513	267	59	8.30	4187	237	57	15070	—		53000	0.9146	65	1.40
18	Tu	8.50	4273	233	55	8.30	3947	220	56	12690	0.7	—	18700	0.9504	72	1.32
19	W	8.45	3925	210	54	8.23	3745	195	52	11765	1.0	—	18700	0.9504	65	1.40
20	Th	8.48	3690	183	50	8.33	3423	173	51	10570	2.7		13900	0.9504	72	1.31
21	F	8.35	3410	170	50	8.30	3357	175	52	10867	2.5		12200	0.9504	69	1.37
22	Sa	8.30	3420	170	50	8.08	3080	160	53	10585	2.2	•	12200	0.9504	69	1.37
23	Su	8.60	2995	145	49	8.33	2920	165	57	10250	1.4	—	12500	0.9504	68	1.39
24	M	8.40	2990	150	50	8.10	3037	160	53	10783	1.9		12200	0.9504	62	1.54
25	Tu	8.37	3397	160	47	8.03	3173	163	51	10930	1.7		12300	0.9504	68	1.39
26	W	8.13	3063	157	51	7.93	3080	150	50	9667	1.9	21	12200	0.9504	71	1.33
27	Th	8.30	2743	133	49	8.10	2953	143	49	9560	2.0	—	12200	0.9504	70	1.36
28	F	8.30	2607	127	49	8.00	2757	140	51	9693	2.1		12000	0.9504	69	1.33
29	Sa	8.10	2863	140	49	7.90	3047	153	51	10383	2.1	—	12300	0.9504	75	1.26
30	Su	8.10	2870	150	52	7.90	2220	155	54	8800	2.5	—	15000	0.9504	79	1.20
31	M	8.10	3050	151	50	7.88	3085	158	51	10758	1.2	—	12400	0.9504	69	1.37
Total		183.83	67280	3462	1138	250.11	87474	4361	1556	288576	72.7	6.5	517600	29.4266	2194	41.5
Avg.		8.36	3058	157	52	8.07	2822	141	50	9309	2.4	22	16700	0.9493	71	1.34
Max.		8.70	5030	270	59	8.35	5620	270	58	16190	3.8	22	53000	0.9504	79	1.54
Min.		8.10	1850	95	47	7.80	1595	93	40	5780	1.0	21	11500	0.9146	62	1.20

* Added Sec Dig. Sludge ☒ Wasted RAS To Primary

Month of May 1976

ANALYTICAL DATA No. 5

1st Sludge Digestion

Date	Day	Total Solids %					Vol. Solids %					pH		Vol. Acids mg/l		Alkalinity mg/l	
		Raw Sludge	Prim Bot.	Prim. Super	Sec Bot.	Sec. Super	Raw Sludge	Prim. Bot.	Prim Super	Sec. Bot.	Sec Super	Prim.	Sec.	Prim	Sec.	Prim.	Sec.
1																	
2																	
3																	
4	Tu	3.6	5.8	0.7	6.2	0.2	72	45	57	47	37	6.9	6.9	110	100	1935	2185
5																	
6																	
7																	
8																	
9																	
10																	
11	Tu	2.0	5.4	0.6	6.0	0.2	65	44	56	47	39	7.0	7.0	125	130	1950	2250
12																	
13																	
14																	
15																	
16																	
17																	
✓ 18																	
19																	
20																	
21																	
22																	
23																	
24																	
25																	
26	W	5.1	6.4	0.9	6.2	0.2	N.D.	43	55	48	42	7.0	7.0	130	110	2240	2415
27																	
28																	
29																	
30																	
31																	
Total		10.7	17.6	2.2	18.4	0.6	137	132	168	142	118	20.9	20.9	365	340	6125	6850
Avg.		3.6	5.9	0.7	6.1	0.2	69	44	56	47	39	6.97	6.97	122	113	2042	2283
Max.		5.1	6.4	0.9	6.2	0.2	72	45	57	48	42	7.0	7.0	130	130	2240	2415
Min.		2.0	5.4	0.6	6.0	0.2	65	43	55	47	37	6.9	6.9	110	100	1935	2185

✓ No sludge hauled This week

Vol. Red. Prim = 65% Sec = 30%

[illegible] Month of May 19[illegible]

WEEKLY H₂S RESULTS IN AIR

PLANT PERIMETER					STATION No.	SLUDGE DRYING BEDS				
Tag on Date + Time	Tag off Date + Time	Elapsed Time Days	Color Grade	H_2S mg/L		Tag on Date + Time	Tag off Date + Time	Elapsed Time Days	Color Grade	H_2S mg/L
5/5@0830	5/12@0845	7	<0.25	<0.00020	L-2	5/3 [illegible]	5/10 [illegible]	7	white	—
"	"	"	"	"	L-4	"	"	"	"	—
"	"	"	"	"	L-6	"	"	"	"	—
"	"	"	"	"	L-8	"	"	"	"	—
5/12@0845	5/19@0845	7	<0.25	<0.00020	L-2	5/10	5/17	7	white	—
"	"	"	"	"	L-4	"	"	"	"	—
"	"	"	"	"	L-6	"	"	"	"	—
"	"	"	"	"	L-8	"	"	"	"	—
5/19@0815	5/26@0830	7	<0.25	<0.00020	L-2	5/17	5/24	7	white	—
"	"	"	"	"	L-4	"	"	"	"	—
"	"	"	"	"	L-6	"	"	"	"	—
"	"	"	"	"	L-8	"	"	"	"	—
5/26@0830	6/2@	7	<0.25	<0.00020	L-2	5/24	5/31	7	white	—
"	"	"	"	"	L-4	"	"	"	"	—
"	"	"	"	"	L-6	"	"	"	"	—
"	"	"	"	"	L-8	"	"	"	"	—
Total										
Avg.										
High										
Low										

ADDITIONAL COMMENTS

5/6/76 New filter pump operable in bio-sump #1

5/10/76 Added 975 lbs. of digester solids to bio-aerator

5/12/76 Added 1447 lbs. " " "

5/12-5/25 No sludges drained from digesters this period

5/13/76 Added 2250 lbs. Of digester solids to bio-aerator

5/17/76 Wasted 4800 lbs. of R.A.S. to primary sed. tanks

5/18/76 Installed D.O. analyser in bio-aerator effluent

5/28/76 Added 375 lbs. of digester solids to bio-aerator

5/29/76 Added 750 lbs. " " "

5/31/76 Added 750 lbs. " " "

Average percent reductions for the month

	Prim.	Sec.	Oxid.#2
B.O.D.	20%	87%	95%
SUS.SOL.	52%	90%	95%

[illegible]

Month of June 19[illegible]

Monthly Analytical Data Sheet No. 1

Date	Day	Sampling Hours	5 Day B.O.D. mg/l				Sus. Solids mg/l				Total Solids				Total Dissolved Sol.			
			Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.
1	Tu	24	287	148	36	—	236	90	50	—	932	736	663	—	696	646	613	—
9	W	24	294	198	26	—	380	98	42	—	1134	783	718	—	754	685	696	—
17	Th	24	218	168	25	—	320	102	27	—	1069	833	700	—	749	731	673	—
Total			799	514	87		936	290	119		3135	2352	2081		2199	2062	1962	
Avg.			266	171	29		312	97	40		1045	784	694		733	687	654	
Max.			294	198	36		380	102	50		1134	833	718		754	731	696	
Min.			218	148	25		236	90	27		932	736	663		696	646	613	

Monthly Analytical Data Sheet No. 2

			Settleable Sol. ml/l				Hydrogen Ion pH				C.O.D. mg/l				LAS mg/l	Cl2 mg/l	Grease mg/l	
Date	Day	Sampling hours	Raw	Prim.	Secondary	Oxid. Pond II	Raw	Prim.	Secondary	Oxid. Pond II	Raw	Prim.	Secondary	Oxid. Pond II	Oxid. Pond II	Secondary	Raw	Secondary
1	Tu	24	15.0	0.3	<0.1	—	8.0	7.9	7.9	—	—	—	—	—	—	<0.1	—	—
9	W	24	18.5	0.8	<0.1	—	8.4	8.0	8.2	—	—	—	—	—	—	<0.1	—	—
17	Th	24	16.0	2.0	<0.1	—	8.4	8.0	8.3	—	—	—	—	—	—	<0.1	—	—
30	W	8													0.86			
Total			49.5	3.1	<0.1		24.8	23.9	24.4						0.86	<0.1		
Avg			16.5	1.0	<0.1		8.3	8.0	8.1						0.86	<0.1		
High			18.5	2.0	<0.1		8.4	8.0	8.3						0.86	<0.1		
Low			15.0	0.3	<0.1		8.0	7.9	7.9						0.86	<0.1		

PLEASANTON WATER [illegible]

Month of June 1976

Monthly Analytical Data Sheet No. 3
Activated Sludge

Date	Day	Mixed Liquor Bio-Sump No. I Avg. pH	Avg. Sus. Sol.	Avg. Set. Sol.	Avg. S.V.I.	Mixed Liquor Bio-Sump No. II Avg. pH	Avg. Sus. Sol.	Avg. Set. Sol.	Avg. S.V.I.	R.A.S. Bio-Aeration Tank Avg. Sus. Sol.	Avg. D.O.	Avg. pH	Waste R.A.S.	R.A.S. MGD.	% Return	% Ash
1	Tu	8.3	4377	220	51	8.0	4543	192	45	13863	0.5	7.5	12,280	0.9504	68	—
2	W	8.2	4693	222	47	7.9	4193	223	47	13943	0.6	7.4	42,533	0.9504	69	22
3	Th	8.4	3943	200	52	8.0	4617	200	48	12910	0.7	7.4	31,620	0.9504	68	—
4	F	8.4	3175	163	51	8.1	3165	165	52	11270	2.7	7.6	13,800	0.9504	80	—
5	Sa	8.4	2820	150	53	8.1	3150	165	53	11420	1.1	7.5	13,650	0.9504	69	—
6	Su	8.3	2830	155	56	8.0	3130	145	47	11415	1.4	7.5	13,600	0.9504	69	—
7	M	8.4	2940	143	49	8.2	[illegible]	133	48	12463	2.3	7.6	14,000	0.4320	30	
8	Tu	8.4	[illegible]	140	45	8.1	2950	135	[illegible]	11205	3.3	7.6	14,000	0.4320	30	—
9	W	8.3	3197	147	46	8.1	3060	150	49	11983	1.2	7.6	24,000	0.4320	30	24
10	Th	8.5	[illegible]	130	48	8.2	2577	133	[illegible]	9817	3.5	7.6	14,000	0.4320	30	
11	F	8.6	2870	140	47	8.3	2290	120	52	9992	3.4	7.6	14,000	0.4320	31	
* 12	Sa	8.1	2410	150	44	7.9	3023	150	49	10510	N.D.	7.6	14,400	0.6100	44	—
13	Su	8.2	2350	140	51	8.1	2430	140	52	10325	2.5	7.7	14,400	0.6100	48	—
14	M	[illegible]	2223	133	58	7.8	2503	133	54	9687	1.9	7.6	14,400	0.6100	44	
15	Tu	8.6	2833	140	49	7.8	3063	157	52	10030	2.3	7.6	14,400	0.6100	46	
16	W	7.6	2577	140	54	7.7	2723	160	59	10015	2.0	7.5	14,400	0.6100	43	27
17	Th	8.3	2593	130	51	7.9	2586	137	54	9253	1.9	7.5	14,400	0.6100	46	—
18	F	7.3	[illegible]	147	55	8.0	2573	150	57	[illegible]	2.2	7.6	14,400	0.6100	46	—
19	Sa	[illegible]	2830	[illegible]	[illegible]	8.1	[illegible]	[illegible]	61	[illegible]	1.3	[illegible]	14,400	0.6100	45	
20	Su	[illegible]	3120	203	65	7.2	3240	200	62	10532	1.4	7.7	14,400	0.6100	46	—
21	M	8.4	2916	190	65	8.1	3299	180	58	10750	2.2	7.7	14,400	0.6100	46	
22	Tu	8.5	2850	180	66	8.2	2923	187	64	10100	1.5	7.7	14,400	0.6100	40	
23	W	8.3	2953	193	65	8.1	2880	190	66	10247	1.6	7.6	14,400	0.6100	42	
24	Th	8.5	2610	158	64	8.1	2813	162	59	9393	1.7	7.5	14,400	0.6100	46	
25	F	8.4	2570	150	66	8.1	2370	150	65	9745	1.1	7.5	14,400	0.6100	44	
26	Sa	8.3	2095	120	58	8.1	2575	140	55	8890	0.5	7.6	14,400	0.6100	41	
27	Su	8.3	2160	135	63	8.1	2030	130	64	8065	1.6	7.7	14,400	0.6100	44	
28	M	—	—	—	—	8.0	2415	145	60	7920	0.5	7.6	14,400	0.6100	45	
29	Tu	—	—	—	—	8.0	[illegible]	130	59	7000	—	7.5	14,400	0.6100	41	
30	W	—	—	—	—	7.7	2150	120	56	7140	—	7.5	14,400	0.6100	43	21
Total		232.2	[illegible]	4297	1491	241	[illegible]	4693	1654	[illegible]	52.4	227.2	[illegible]	19.4524	1412	94
Avg.		8.3	2947	159	55	8.0	2888	157	55	10217	1.9	7.6	16,138	0.6484	47	24
Max.		8.6	4693	222	66	8.3	4543	223	66	13943	3.5	7.7	42,533	0.9504	80	27
Min.		7.6	2095	120	44	7.7	2030	120	45	7140	0.5	7.4	12,280	0.4320	30	21

* R.A.S. Flow Estimated

Monitor [illegible]

Monthly Analytical Data Sheet No. 4

			Avg Total H_2S		Avg. Dissolved H_2S			max. [illegible]	Dissolved Oxygen			min. [illegible]	P H		Settleable Matter		Fluorides	[illegible]
Date	Day	Sampling Hours	Filter Effl.	Sec. Effl.	Filter Effl	Sec. Effl.	Oxid. Pond No. 2 Effl.	Sec. Effl.	Sec. Effl.	Oxid. Pond No. 1 Effl.	Oxid. Pond No. 2 Effl.	Oxid. Pond No 2 Effl.	Raw Infl.	Sec. Effl	Sec. Effl.	Oxid. Pond No. 2 Effl.	Sec. Effl. Grab Samples	Sec. Effl. 9hr. Comp
1	Tu	8	0.85	0.11	<0.1	<0.1	<0.1	<0.1	1.0	5.8	6.4	4.3	8.9	—	—	—	—	29
2	W	8	1.00	0.15	<0.1	<0.1	<0.1	<0.1	1.2	6.1	9.0	6.0	8.9	—	—	—	—	39
3	Th	8	0.76	0.13	0.14	<0.1	<0.1	<0.1	0.6	6.9	6.9	6.3	8.9	—	—	—	—	38
4	F	6	0.53	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	5.8	10.6	8.5	8.9	—	—	—	—	33
5	Sa	4	0.43	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	7.2	—	—	8.9	—	—	—	—	36
6	Su	4	0.33	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	7.6	16.0	—	8.8	—	—	—	—	42
7	M	8	0.35	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	7.6	9.9	5.9	8.9	—	—	—	—	37
8	Tu	6	0.37	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	6.9	15.2	—	9.0	—	—	—	—	32
9	W	8	0.40	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	7.9	11.0	6.1	8.9	—	—	—	0.58	42
10	Th	8	0.54	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	7.6	11.2	6.1	8.9	8.3	—	—	—	32
11	F	3	0.60	<0.1	<0.1	<0.1	<0.1	<0.1	0.6	7.4	11.1	5.7	8.7	—	—	—	—	—
12	S.	4	0.43	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	6.8	16.1	—	8.9	7.2	—	—	—	32
13	Su	4	0.25	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	6.5	12.2	—	8.9	7.4	—	—	—	32
14	M	8	0.26	<0.1	0.08	<0.1	<0.1	<0.1	0.6	6.2	10.1	7.8	8.9	8.0	—	—	—	28
15	Tu	8	0.36	0.08	<0.1	<0.1	<0.1	<0.1	0.5	7.5	14.3	8.6	8.8	8.1	—	—	—	41
16	W	8	0.15	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	7.9	9.6	9.6	8.9	7.9	—	—	—	30
17	Th	8	0.25	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	7.4	9.9	8.8	8.8	8.0	—	—	—	34
[illegible]	F	6	0.17	<0.1	<0.1	<0.1	<0.1	[illegible]	0.4	5.6	[illegible]	9.1	7.7	7.5	—	—	—	40
9	Sa	5	0.18	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	6.3	11.6	8.0	8.9	7.9	—	—	—	28
0	Su	5	0.35	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	5.7	10.5	5.5	8.9	8.1	—	—	—	20
1	M	5	0.48	<0.1	0.12	<0.1	<0.1	<0.1	0.4	7.1	17.0	—	8.5	8.3	—	—	—	80
2	Tu	7	0.41	<0.1	0.14	<0.1	<0.1	<0.1	0.4	11.7	13.0	8.1	8.9	7.9	—	—	—	54
	W	8	0.31	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	8.0	12.3	11.0	8.9	8.3	—	—	—	36
4	Th	8	0.21	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	8.0	14.0	10.6	8.9	7.8	—	—	—	44
5	F	6	0.24	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	7.9	14.4	10.9	8.2	8.3	—	—	—	55
6	Sa	4	0.33	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	7.1	19.2	—	8.8	7.9	—	—	—	44
7	Su	5	0.26	<0.1	<0.1	<0.1	<0.1	<0.1	0.5	7.3	19.4	—	8.8	7.9	—	—	—	68
	M	1	—	—	—	—	<0.1	—	—	6.3	12.6	—	—	—	—	—	—	—
	Tu	1	—	—	—	—	<0.1	—	—	6.4	13.7	—	—	—	—	—	—	—
	W	1	—	—	—	—	<0.1	—	—	5.5	16.6	—	—	—	—	—	—	—
Total			10.86	0.47	0.48	<0.1	<0.1	<0.1	14.1	212	362.9	146.9	239.2	134.8			0.58	1222
Avg.			0.40	0.02	0.02	<0.1	<0.1	<0.1	0.5	7.1	12.6	7.7	8.9	7.9			0.58	39
Max.			1.00	0.15	0.14	<0.1	<0.1	<0.1	1.2	11.7	19.4	11.0	9.0	8.3			0.58	80
Min.			0.15	<0.1	<0.1	<0.1	<0.1	<0.1	0.3	5.5	6.4	5.5	8.5	7.2			0.58	20

ANALYTICAL DATA SHEET No. 5

SLudge DigesTion

DATE	DAY	TOTAL Solids %					Vol. Solids %					pH		Vol. Acids mg/L		ALKALINITY mg/L	
		Raw Sludge	Prim Bot.	Prim Super.	Sec Bot.	Sec. Super.	Raw Sludge	Prim Bot.	Prim Super.	Sec. Bot.	Sec. Super.	Prim.	Sec.	Prim	Sec.	Prim.	Sec.
2	W	3.3	6.9	1.2	6.2	0.2	71	40	56	47	47	7.0	7.0	270	120	2470	2245
9	W	2.7	8.8	1.2	5.7	0.2	58	32	51	43	43	7.1	7.0	200	160	2510	2480
16	W	3.2	12.1	1.6	6.2	0.3	66	35	54	47	48	7.0	7.0	250	300	2900	2750
30	W	4.3	6.2	1.3	6.2	0.2	68	46	53	45	51	7.3	7.2	150	110	3350	3145
TOTAL		13.5	34	5.3	24.3	0.9	263	153	214	182	189	28.4	28.2	820	690	11230	10620
Avg.		3.4	8.5	1.3	6.1	0.2	66	38	54	46	47	7.1	7.1	218	173	2808	2655
Max.		4.3	12.1	1.6	6.2	0.3	71	46	56	47	51	7.3	7.2	270	300	3350	3145
Min.		2.7	6.2	1.2	5.7	0.2	58	32	51	43	43	7.0	7.0	150	110	2470	2245

Vol. Red. Prim= 62% Sec= 27%

MONTH OF ——— 19——

WEEKLY. H_2S, RESULTS IN AIR. Sheet No. 6.

STATION No.	PLANT PERIMETER Tag On DATE + TIME	Tag OFF DATE + TIME	Elapsed TIME DAYS	COLOR GRADE	H_2S mg/L	STATION No.	SLUDGE DRYING BEDS Tag ON DATE + TIME	Tag OFF DATE + TIME	Elapsed TIME DAYS	COLOR GRADE	H_2S mg/L
1	6/2@0830	6/9@0900	7	<0.25	<0.00020	L-2	5/31@0830	6/7@0830	7	white	—
2	"	"	"	"	"	L-4	"	"	"	"	—
3	"	"	"	"	"	L-6	"	"	"	"	—
4	"	"	"	"	"	L-8	"	"	"	"	—
1	6/9@0900	6/16@0830	7	<0.25	<0.00020	L-2	6/7@0830	6/16@0830	9	white	—
2	"	"	"	"	"	L-4	"	"	"	"	—
3	"	"	"	"	"	L-6	"	"	"	"	—
4	"	"	"	"	"	L-8	"	"	"	"	—
1	6/16@0830	6/23@0900	7	<0.25	<0.00020	L-2	6/16@0830	6/21@0830	5	white	—
2	"	"	"	"	"	L-4	"	"	"	"	—
3	"	"	"	"	"	L-6	"	"	"	"	—
4	"	"	"	"	"	L-8	"	"	"	"	—
1	6/23@0900	6/30@0830	7	<0.25	<0.00020	L-2	6/21@0830	6/28@0830	7	white	—
2	"	"	"	"	"	L-4	"	"	"	"	—
3	"	"	"	"	"	L-6	"	"	"	"	—
4	"	"	"	"	"	L-8	"	"	"	"	—
Total											
Avg.											
High											
Low											

ADDITIONAL COMMENTS June 1976

6/2 Wasted 4,800 lbs. R.A.S. to primary sed. tanks

6/3 Wasted 2,400 lbs. R.A.S. to primary sed. tanks

6/4 Installed new motor on Bio-sump No. 2 Pump No. 137

6/7 Started R.A.S. constant waste @ 14,000 g.p.d. to primary sed. tanks
Added 4 min. of pump time to sludge pump No. 144

6/8 Added 750 lbs. of digester solids to Bio-aerator

6/10 " 1500lbs. " " "

6/11 Installed R.A.S. metering pump - pump rate = 10 g.p.m.
Secondary digester siphoned 65,000 gal. to headworks
New Filter pump operable in Bio-sump No.1

6/15 Added 1500 lbs. of digester solids to Bio-aerator
Charcoal scrubbers negative on H2S saturation checkout

Average percentage reductions for the month

	Primary Effl.	Secondary Clar. Effl.
B.C.D.	36%	89%
Sus. Sol.	69%	87%

PLEASANTON WATER [illegible] Month of JULY 19 76

Monthly ANALYTICAL DATA SHEET No. 1

DATE	DAY	SAMPLING HOURS	5 DAY B.O.D. mg/L RAW	5 DAY B.O.D. mg/L PRIM.	5 DAY B.O.D. mg/L SEC. EFFL.	5 DAY B.O.D. mg/L OXID. POND No. II EFFL.	SUS. SOLIDS mg/L RAW	SUS. SOLIDS mg/L PRIM.	SUS. SOLIDS mg/L SEC. EFFL.	SUS. SOLIDS mg/L OXID. POND No. II EFFL.	TOTAL SOLIDS RAW	TOTAL SOLIDS PRIM.	TOTAL SOLIDS SEC. EFFL.	TOTAL SOLIDS OXID. POND No. II EFFL.	TOTAL DISSOLVED SOL. RAW	TOTAL DISSOLVED SOL. PRIM.	TOTAL DISSOLVED SOL. SEC. EFFL.	TOTAL DISSOLVED SOL. OXID. POND No. II EFFL.
7	W	24	267	170	39	—	356	96	84	—	1088	793	750	—	732	697	666	—
15	T	24	24[illegible]	163	21	—	312	92	28	—	1000	743	660	—	688	651	632	—
21	W	24	280	155	25	—	260	80	25	—	1030	778	665	—	770	698	640	—
[illegible]	[illegible]	[illegible]	266	[illegible]	20	—	392	N.D.	29	—	997	N.D.	654	—	605	N.D.	625	—
TOTAL			1053	488	105		1320	268	166		4115	2314	2729		2795	2046	2563	
AVG.			263	163	26		330	89	42		1029	771	682		699	682	641	
MAX.			280	170	39		392	96	84		1088	793	750		770	698	666	
MIN.			24[illegible]	155	20		260	80	25		997	743	654		605	651	625	

Month July '' 76

Monthly Analytical Data Sheet No. 2

Date	Day	Sampling hours	Settleable Sol. ml/l Raw	Settleable Sol. ml/l Prim.	Settleable Sol. ml/l Secondary	Settleable Sol. ml/l Oxid. Pond II	Hydrogen Ion pH Raw	Hydrogen Ion pH Prim.	Hydrogen Ion pH Secondary	Hydrogen Ion pH Oxid. Pond II	C.O.D. mg/l Raw	C.O.D. mg/l Prim.	C.O.D. mg/l Secondary	C.O.D. mg/l Oxid. Pond II	L.A.S. mg/l Oxid. Pond II	Cl2 mg/l Secondary	Grease mg/l Fluoride Raw	Grease mg/l Fluoride Secondary
7	W	24	18.0	1.0	0.4	—	8.1	7.8	8.0	—	—	—	—	—	—	<0.1	—	0.88
15	Th	24	19.0	1.5	<0.1	--	8.0	7.7	8.1	—	—	—	—	—	—	<0.1	—	0.80
21	W	24	18.0	1.3	<0.1	—	8.1	7.8	8.1	—	—	—	—	—	—	<0.1	—	0.85
27	Tu	24	19.0	N.C.	<0.1	—	8.5	N.C.	8.2	—						<0.1	—	0.65
Total			74	3.8	0.4		32.7	23.3	32.4							<0.1		3.18
Avg.			18.5	1.3	0.1		8.2	7.8	8.1							<0.1		0.80
High			19	1.5	0.4		8.5	7.8	8.2							<0.1		0.88
Low			18	1.0	<0.1		8.0	7.7	8.0							<0.1		0.65

PLEASANTON WATER POLLUTION CONTROL PLANT

MONTH OF: 1/ 19 76

MONTHLY ANALYTICAL DATA SHEET No 3

ACTIVATED SLUDGE

DATE	DAY	Daily Flow	MIXED LIQUOR Bio-Sump No. I Avg. Sus. Sol.	Avg. Set. Sol.	Avg. S.V.I.	MIXED LIQUOR Bio-Sump No. II Avg pH	Avg. Sus. Sol.	Avg. Set. Sol.	Avg. S.V.I.	BIO-AERATION TANK Avg. Sus. Sol.	Avg D.O.	Avg. pH	R.A.S. Waste R.A.S. gal	R.A.S. MGD	% Return	%
1	Th	1.455				8.3	2225	100	48	665	—	7.6	14,400	0.6100	42	
2	F	1.428				8.3	1490	85	57	405	—	7.7	14,400	0.6100	43	
3	Sa	1.423				8.1	1315	70	54	145	—	7.7	14,400	0.6100	43	
4	Su	1.334				8.2	1615	83	51	150	—	7.7	14,400	0.6100	46	
5	M	1.497				8.2	2715	135	50	720	—	7.7	14,400	0.6100	41	
6	Tu	1.534				7.9	3515	188	54	1630	—	7.5	14,400	0.6100	40	
7	W	1.471				7.9	3590	200	56	960	—	7.5	14,400	0.6100	41	
8	Th	1.443				7.9	3045	190	63	1800	—	7.6	14,400	0.6100	42	
9	F	1.479				7.9	2900	160	56	335	—	7.5	14,400	0.6100	41	23
10	Sa	1.365				8.0	2525	155	61	565	—	7.4	14,400	0.6100	45	
11	Su	1.350				8.2	2460	135	55	[illegible]	—	7.6	14,400	0.6100	45	
12	M	1.392				8.0	2470	138	56	4025	—	7.6	14,400	0.6100	44	
13	Tu	1.424				7.8	2755	128	47	383	—	7.5	14,400	0.6100	43	
14	W	1.312				7.5	2310	125	54	750	—	7.3	14,400	0.6100	46	
15	Th	1.314				7.7	2160	130	60	310	—	7.4	14,400	0.6100	46	
16	F	1.363				7.7	1755	103	59	6390	—	7.4	14,400	0.6100	45	27
17	Sa	1.302				8.0	1390	78	54	820	—	7.6	14,400	0.6100	47	
18	Su	1.209				7.9	1080	55	51	720	—	7.5	6,000	0.6100	49	
19	M	1.298				8.0	1290	50	39	4420	—	7.6	0	0.6100	47	
20	Tu	[illegible]				7.8	1410	50	35	4420	—	7.6	0	0.6100	48	
21	W	1.345				8.0	2265	100	45	7325	—	7.6	3,300	0.6100	45	
22	Th	1.290				7.7	4500	190	42	1300	—	7.5	14,400	0.6100	47	
23	F	1.392				7.7	4630	190	41	1390	—	7.4	14,400	0.6100	44	26
24	Sa	1.311				8.0	4240	200	47	1930	—	7.6	14,400	0.6100	46	
25	Su	1.281				8.0	3820	200	52	1950	—	7.6	14,400	0.6100	48	
26	M	1.358				7.8	3460	200	58	1610	—	7.5	14,400	0.6100	45	
27	Tu	1.359				7.7	3680	190	52	4920	—	7.5	14,400	0.6100	45	
28	W	1.312				8.0	[illegible]	150	58	[illegible]	—	7.5	14,400	0.6100	46	
29	Th	1.234				[illegible]	2850	140	56	[illegible]	—	[illegible]	14,400	[illegible]	47	
30	F	1.393				7.8	2600	140	54	8470	—	7.5	14,400	0.6100	44	
31	Sa	1.295				8.2	2215	120	55	[illegible]	—	7.4	14,400	0.6100	47	
TOTAL		42.323				246.2	80945	4201	1620	[illegible]953		233.7	378,[illegible]00	0.6100	1388	76
AVG.		1.325				7.9	2611	136	52	8547		7.5	13,728	0.6100	45	25
MAX.		1.534				8.3	4630	200	63	1390		7.7	14,400	0.6100	49	27
MIN.		1.209				7.7	1080	50	35	3720		7.3	0	0.6100	40	23

Month of Ju ly 76

Monthly Analytical Data Sheet No. 4

			AV. TOTAL H2S		AVG. DISSOLVED H2S		H2S	MAX. OCCURRENCE	DISSOLVED		[illegible]	MIN. [illegible]	PH		SETTLEABLE MATTER		CHLORIDES	[illegible]
DATE	DAY	Sampling Hours	Filter Effl.	Sec. Effl.	Filter Effl.	Sec. Effl.	Oxid. Pond No. 2 Effl.	Sec. Effl.	Sec. Effl.	Oxid. Pond No. 2 Effl.	Oxid. Pond No. 2 Effl.	Oxid. Pond No 2 Effl.	Raw Infl.		Sec. Effl.	Oxid. Pond No. 2 Effl.	Sec. Effl. Grab Sample	[illegible]
1	Th						<0.1			6.2	15.[illegible]					<0.1		
2	F						<0.1			7.7	22.0					<0.1		
3	Sa						<0.1			5.3	14.[illegible]					<0.1		
4	Su						<0.1			4.9	13.[illegible]					<0.1		
5	M						<0.1			7.4	12.8					<0.1		
6	Tu						<0.1			7.4	19.6					<0.1		
7	W						<0.1			8.1	19.2					<0.1		
8	Th						<0.1			7.0	19.0					<0.1		
9	F						<0.1			7.0	32.[illegible]					<0.1		
10	Sa						<0.1			8.4	[illegible]					<0.1		
11	Su						<0.1			6.4	21.4					<0.1		
12	M						N.D.			N.D.	N.D.					N.D.		
13	Tu						N.D.			N.D.	N.D.					N.D.		
14	W						N.D.			N.D.	N.D.					N.D.		
15	Th						N.D.			N.D.	N.D.					N.D.		
16	F						<0.1			7.8	15.[illegible]					<0.1		
17	Sa						<0.1			7.8	15.[illegible]					<0.1		
18	Su						<0.1			7.6	15.2					<0.1		
19	M						<0.1			7.0	[illegible]					<0.1		
20	Tu						<0.1			7.0	18.2 *					<0.1		
21	W						<0.1			6.0	23.4					<0.1		
22	Th						<0.1			6.8	24.4					<0.1		
23	F						<0.1			7.0	29.0					<0.1		
24	Sa						<0.1			6.2	20.4					<0.1		
25	Su						<0.1			6.6	27.6					<0.1		
26	M						<0.1			7.2	23.4					<0.1		
27	Tu						<0.1			7.4	23.8					<0.1		
28	W						<0.1			6.4	[illegible]					0.3		
29	Th						<0.1			7.8	15.8					0.5		1.12
30	F						<0.1			7.4	22.[illegible]					<0.1		
31	Sa						<0.1			6.0	15.8					<0.1		
TOTAL							<0.1			18[illegible].8	5[illegible]					0.8		1.12
AVG.							<0.1			7.0	20.6					<0.1		1.12
MAX.							<0.1			8.4	32.0					0.5		1.12
MIN.							<0.1			4.9	12.8					<0.1		1.12

[illegible] Pond No. 2 [illegible]

MONTH OF JULY 76

ANALYTICAL DATA SHEET No. 5

SLudge Digestion

DATE	DAY	TOTAL Solids %					Vol. Solids %					PH		Vol Acids mg/L		ALKALINITY mg/L	
		RAW Sludge	PRIM. BOT.	PRIM. Super	SEC BOT.	SEC. Super	RAW Sludge	PRIM BOT.	PRIM Super	SEC. BOT.	SEC Super	PRIM.	SEC.	PRIM.	SEC.	PRIM.	SEC.
9	F	2.8	6.7	1.6	2.5	0.3	68	39	ND	44	41	7.2	7.3	140	140	3000	3195
16	F	2.0	5.7	1.2	5.8	0.2	4[illegible]	32	3[illegible]	ND	37	7.3	7.3	160	120	2890	3390
23	F	3.4	7.9	1.4	6.9	0.3	55	41	51	45	52	7.3	7.4	130	110	3125	3435
[illegible]	[illegible]	[illegible]	6.8	1.6	[illegible]	0.3	62	41	4[illegible]	43	[illegible]	7.2	7.4	160	100	[illegible]	[illegible]
TOTAL		11.2	[illegible]	[illegible]	22.3	1.1	227	153	[illegible]	132	177	29	29.4	590	470	[illegible]	[illegible]
AVG.		[illegible]	[illegible]	1.4	[illegible]	0.3	57	38	45	44	[illegible]	7.3	7.4	148	118	[illegible]	3203
MAX.		3.4	[illegible]	[illegible]	[illegible]	0.3	68	[illegible]	51	45	52	7.3	7.4	160	140	3125	[illegible]
MIN.		2.0	5.7	1.2	2.5	0.2	55	32	3[illegible]	[illegible]	37	7.2	7.3	130	100	2890	3195

Vol. Red. Prim = 5[illegible] % Sec = [illegible] %

Month of July

WEEKLY H_2S RESULTS IN AIR. SHEET No. 6

Station No.	PLANT PERIMETER Tag on Date & Time	Tag off Date & Time	Elapsed Time Days	Color Grade	H_2S mg/L	Station No.	SLUDGE DRYING BED'S Tag on Date & Time	Tag off Date & Time	Elapsed Time Days	Color Grade	H_2S mg/L
1	6/[illegible] 0830	7/[illegible]	7	<0.25	<0.00020	1-2	6/28 [illegible]	7/5 [illegible]	7	<0.25	<0.00020
2	"	"	"	"	"	1-4	"	"	"	"	"
3	"	"	"	"	"	1-6	"	"	"	"	"
4	"	"	"	"	"	1-8	"	"	"	"	"
1	7/[illegible]	7/[illegible]	7	<0.25	<0.00020	1-2	7/5 [illegible]	7/12 [illegible]	7	<0.25	<0.00020
2	"	"	"	"	"	1-4	"	"	"	"	"
3	"	"	"	"	"	1-6	"	"	"	"	"
4	"	"	"	"	"	1-8	"	"	"	"	"
1	7/[illegible]	7/[illegible]	5	<0.25	<0.00020	1-2	7/[illegible]	7/19 0800	7	<0.25	<0.00020
2	"	"	"	"	"	1-4	"	"	"	"	"
3	"	"	"	"	"	1-6	"	"	"	"	"
4	"	"	"	"	"	1-8	"	"	"	"	"
1	7/[illegible] 0800	7/[illegible] 0730	7	0.5	0.49	1-2	7/19 [illegible]	7/26 [illegible]	7	<0.25	<0.00020
2	"	"	"	<0.25	<0.00020	1-4	"	"	"	"	"
3	"	"	"	"	"	1-6	"	"	"	"	"
4	"	"	"	"	"	1-8	"	"	"	"	"
1	[illegible]	[illegible]	7	<0.25	<0.00020	1-2	7/[illegible]	8/2 [illegible]	7	<0.25	<0.00020
2	"	"	"	"	"	1-4	"	"	"	"	"
3	"	"	"	"	"	1-6	"	"	"	"	"
4	"	"	"	"	"	1-8	"	"	"	"	"

Total
Avg.
Avg.
No.

ADDITIONAL COMMENTS

July 1976

7/8 to 7/29 Continous dissolved oxygen studies of the bio-aerater indicate that shutting off of one blower between the hours of 12:00 midnight and 12:00 noon will eliminate the problem of over aeration during this period. It is recommended that a timer switch for the blowers be installed to accomplish this and that future planning include provisions for an in line D. O. analyser and recorder for this system in order to maintain maximum efficiency from the biological portion of the plant.

7/19 to 7/22 Dissolved oxygen profile studies of oxidation pond #2 indicate that higher D.O. levels can be obtained by shutting off all aeraters during daylight hours. Oxygen levels with the aeraters running averaged 12 ppm. With the aeraters off the oxygen levels were continously above 10 ppm.

7/19 to 7/26 The weekly plant perimeter sufide monitoring showes some sulfides generated in the area of station #1. The problem was traced to the scum sump in the plant headworks area. Improvements to the sump cover and close attention to operational procedures should eliminate this problem.

7/20 The monthly check of the bio-charcoal scrubber shows the bottom level has lost it's ability to scrub out sulfides.

7/22 Installation of new ozonator completed. Tests will be conducted during August to determine the output capabilities of the new equipment.

7/30 Installed flotation boom in the secondar clarifier. This simple device is functioning as anticipated and will increase the clarifers removal efficiency of suspended solid materials.

7/30 A three month composite of the weekly 24 hour secondary effluent composites was made for the purpose of determining heavy metal concentrations that could be attributed to industrial discharges. The results show no apparent problems from industrial sources. April, May, June 1976

Element:	Concentration in parts per billion:
Cadmium	5
Chromium	9
Copper	63
Lead	15
Zinc	31
Iron	154
Silver	2
Manganese	9
Arsenic	<1
Barium	160

Average percentage reductions for the month

	Primary Effl.	Sec. Clar. Effl.
B.O.D.	38%	90%
Sus. Sol.	73%	87%

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of *DEC* 19*76*

WEATHER AND FLOW DATA

DATE	DAY	WEATHER DATA					SEWAGE FLOW								RAW INFL. LIME USAGE Lbs/Day
		TEMP. °F		PRECIPITATION	EVAPORATION	Wind Speed WIND DIRECTION & MPH	MILLION GALLONS						EFFL. RATE MGD		
							INFLUENT M.G.D.	EFFLUENT							
		MAX.	MIN.	INCHES	INCHES			TOTAL M.G.D.	100 acre	62 acre	37 acre		MAX.	MIN.	
1	W	62	30	0		E@3		1.309	0.700	0.609	0.300		2.9	0.1	1500
2	Th	62	28	0		NE@5		1.390	0.600	0.590	0.300		"	"	1350
3	F	64	30	0		S@1		1.309	0.700	0.609	0.300		"	"	1150
4	Sa	59	40	0		NW@4		1.358	0.858	0.800	0.300		"	"	900
5	Su	66	32	0		NW@7		1.352	0.652	0.600	0.300		"	"	1000
6	M	60	30	0		E@5		1.368	0.868	0.800	0.600		"	"	1000
7	Tu	62	30	0		W@4		1.373	0.700	0.673	0.300		"	"	850
8	W	62	36	0		NW@2		1.309	0.700	0.609	0.300		"	"	1000
9	Th	60	42	0		W@9		1.287	0.500	0.487	0.300		"	"	1050
10	F	61	29	0		E@7		1.241	0.641	0.600	0.300		"	"	900
11	Sa	59	28	0		SW@3		1.353	0.653	0.600	0.600		"	"	1000
12	Su	62	28	0		NE@6		1.332	0.732	0.700	0.300		"	"	950
13	M	60	28	0		N@4		1.342	0.742	0.700	0.300		"	"	950
14	Tu	61	27	0		N@2		1.342	0.692	0.650	0.300		"	"	0
15	W	66	28	0		W@2		1.256	0.656	0.600	0.600		"	"	550
16	Th	57	26	0		N@4		1.280	0.680	0.600	0.300		"	"	800
17	F	57	24	0		NE@1		1.348	0.698	0.650	0.600		"	"	950
18	Sa	61	28	0		W@2		1.323	0.678	0.650	0.300		"	"	1000
19	Su	62	28	0		E@1		1.290	0.740	0.650	0.300		"	"	1100
20	M	58	28	0		W@1		1.375	0.725	0.650	0.300		"	"	900
21	Tu	60	28	0		NW@1		1.366	0.616	0.650	0.300		"	"	950
22	W	56	34	0		NW@1		1.323	0.623	0.600	0.300		"	"	1150
23	Th	56	27	0		W@1		1.385	0.735	0.650	0.300		"	"	950
24	F	60	28	0		N@1		1.446	0.696	0.650	0.600		"	"	1200
25	Sa	56	26	0		NW@2		1.202	0.259	0.740	0.300		"	"	1250
26	Su	52	26	0		W@1		1.287	0.687	0.600	0.300		"	"	1200
27	M	62	26	0		W@2		1.424	0.724	0.700	0.300		"	"	1050
28	Tu	54	26	0		NW@2		1.306	0.700	0.606	0.300		"	"	1050
29	W	53	42	0		SW@2		1.305	0.700	0.605	0.300		"	"	1050
30	Th	58	42	0.89		S@10		1.371	0.571	0.400	0.300		"	"	1050
31	F	60	34	0.27		NE@3		1.385	0.825	0.560	0.300		"	"	1100
TOTAL		1855	942	1.16		99		41.451	21.613	19.838	10.800		29.9	3.1	30900
AVERAGE		60	30	0.04		3		1.337	0.697	0.640	0.348		2.9	0.1	997
MAXIMUM		66	42	0.89		10		1.424	0.835	0.800	0.600		2.9	0.1	1500
MINIMUM		52	26	0		1		1.262	0.500	0.400	0.300		2.9	0.1	0

Month of [illegible] 19[illegible]

Monthly Analytical Data Sheet No. 1

			5 Day B.O.D. mg/l				Sus. Solids mg/l				Total Solids				Total Dissolved Sol.			
Date	Day	Sampling Hours	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.
1	W	24	247	146	26	—	320	76	44	—	1010	748	694	—	690	672	650	—
7	Tu	24	248	156	51	—	224	36	22	—	943	735	697	—	719	699	675	—
14	Tu	24	312	186	55	—	200	50	41	—	865	739	668	—	665	689	627	—
21	Tu	24	285	174	56	—	252	58	41	—	1000	771	725	—	748	713	684	—
28	Tu	24	358	192	51	—	212	102	31	—	979	868	792	—	767	766	761	—
Total			1450	854	239		1208	322	179		4797	3861	3576		3589	3539	3397	
Avg.			290	171	48		242	64	36		959	772	715		718	708	679	
Max.			358	192	56		320	102	44		1010	868	792		767	766	761	
Min.			247	146	26		200	36	22		865	735	668		665	689	627	

DE[illegible] 76

Monthly Analytical Data Sheet No. 2

			Settleable Sol. ml/l				Hydrogen Ion pH				[illegible] N mg/l		Nitrate N mg/l		L.A.S. mg/l	Cl_2 mg/l	[illegible] mg/l
Date	Day	Sampling hours	Raw	Prim	Secondary	Oxid Pond II	Raw	Prim.	Secondary	Oxid. Pond II	Prim.	Secondary	Secondary	Oxid Pond II	Secondary	Secondary	Secondary
1	W	24	12.0	<0.1	0.1	—	8.0	8.0	7.9	—	—	—	—	—	—	<0.1	1.00
7	Tu	24	9.0	<0.1	<0.1	—	8.3	8.0	7.9	—	—	—	—	—	—	<0.1	—
14	Tu	24	9.0	<0.1	0.1	—	7.2	7.3	7.6	—	—	—	—	—	—	<0.1	0.80
21	Tu	24	14.5	<0.1	<0.1	—	8.6	8.3	7.7	—	—	—	—	—	—	<0.1	0.85
28	Tu	24	10.0	0.5	<0.1	—	8.6	8.[illegible]	7.[illegible]	—	—	—	—	—	—	<0.1	0.77
Total			54.5	0.5	0.2		40.7	39.8	38.7							<0.1	3.42
Avg			10.9	0.1	<0.1		8.1	8.0	7.7							<0.1	0.68
High			14.5	0.5	0.1		8.6	8.3	7.9							<0.1	1.00
Low			9.0	<0.1	<0.1		7.2	7.3	7.6							<0.1	0.77

Grab Samples - Daily

Data Sheet No. 3

DEC 197

MONTH YEAR DATE	Flow Rate M.G.	Time of Sampling	Station E-1 D.O. mg/L	Station E-1 Dis. H2S mg/L	Station E-1 pH	Station ER-1 D.O. mg/L	Station ER- D.O. mg/L	Station ER- Dis. H2S mg/L	Station ER- Set. Sol. ml/L
1	1.6	1800	1.0	<0.1	7.8	7.0	6.8	<0.1	<0.1
2	1.7	1800	1.0	<0.1	7.7	7.4	7.8	<0.1	<0.1
3	1.6	1700	.5	<0.1	7.4	7.2	7.4	<0.1	<0.1
4	2.0	1700	.8	<0.1	7.4	7.4	9.0	<0.1	<0.1
5	1.8	1700	.7	<0.1	7.5	8.0	8.8	<0.1	<0.1
6	[illegible]	1630	.8	<0.1	7.5	6.8	8.2	<0.1	<0.1
7	1.8	1630	[illegible]	0.1	7.6	6.2	8.8	<0.1	<0.1
8	1.9	1630	.8	<0.1	7.6	5.4	9.2	<0.1	<0.1
9	2.0	1630	1.0	<0.1	7.5	6.2	9.4	<0.1	<0.1
10	1.4	1630	1.0	<0.1	7.6	6.8	9.4	<0.1	<0.1
11	2.5	1630	.4	<0.1	7.5	6.2	9.0	<0.1	<0.1
12	1.8	1630	<0.1	<0.1	7.5	6.4	9.4	<0.1	<0.1
13	1.6	1630	.6	<0.1	7.5	7.6	7.8	<0.1	<0.1
14	1.6	1630	.8	<0.1	7.2	6.4	9.4	<0.1	<0.1
15	1.6	1630	.8	<0.1	7.4	7.0	8.0	<0.1	<0.1
16	1.6	1630	.8	<0.1	7.3	7.0	8.8	<0.1	<0.1
17	1.4	1630	.8	<0.1	7.2	7.6	14.6	<0.1	<0.1
18	1.3	1630	.8	<0.1	7.4	6.6	8.2	<0.1	<0.1
19	1.4	1630	[illegible]	<0.1	7.2	7.1	8.9	<0.1	<0.1
20	1.9	1630	.3	0.1	7.3	5.8	8.2	<0.1	<0.1
21	1.9	1630	.2	<0.1	7.4	5.8	7.0	<0.1	<0.1
22	1.7	1630	.3	<0.1	7.3	6.0	7.5	<0.1	<0.1
23	2.2	1630	.3	<0.1	7.6	5.2	7.1	<0.1	<0.1
24	2.5	1630	.2	<0.1	7.5	5.3	7.8	<0.1	<0.1
25	2.3	1630	.2	<0.1	7.4	6.4	7.7	<0.1	<0.1
26	2.2	1630	.3	<0.1	7.5	6.2	7.6	<0.1	<0.1
27	1.9	1630	1.0	<0.1	7.7	7.0	[illegible]	<0.1	<0.1
28	1.8	1630	.4	<0.1	7.6	6.8	8.[illegible]	<0.1	<0.1
29	1.[illegible]	[illegible]	.4	<0.1	7.6	7.2	8.8	<0.1	<0.1
30	1.7	1630	.2	<0.1	7.6	[illegible]	7.6	<0.1	<0.1
31	2.0	1630	.2	<0.1	7.5	7.0	8.2	<0.1	<0.1
Total	55.5	51095	18.2	0.2	232.2	205.8	262.2	<0.1	<0.1
Max.	2.5	1800	1.0	0.1	7.8	8.0	14.6	<0.1	<0.1
Min.	1.3	1630	<0.1	<0.1	7.2	5.2	6.8	<0.1	<0.1
Avg.	1.79	1648	0.6	<0.1	7.5	6.0	8.5	<0.1	<0.1

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of DEC 1976

Monthly Analytical Data Sheet No. 4
Activated Sludge

DATE	DAY	PLANT FLOW M.G.D.	BIO-AERATOR FLOW 85			MIXED LIQUOR BIO-SUMP No. II				R.A.S. BIO-AERATION TANK						
			No. 146 Hours On	No. 147 Hours On	Million C.F.D.	Avg pH	Avg Sus. Sol.	Avg. Set. Sol.	Avg S.V.I.	Avg Sus. Sol.	Avg. D.O.	Avg. pH	Waste R.A.S.	R.A.S. M.G.D.	% Return	% Ash
1	W	1.309	12	24	0.680	7.6	2680	[illegible]	52	[illegible]232[illegible]		7.2	15300	1.18	90	
2	Th	1.290	24	12	"	7.8	3140	200	63	[illegible]590		7.6	21600	"	85	
3	F	1.309	12	24	"	7.1	2590	160	6[illegible]	[illegible]220		7.0	21600	"	90	
4	Sa	1.358	24	12	"	7.4	2880	170	59	[illegible]530		7.2	21600	"	87	
5	Su	1.352	12	24	"	7.3	2540	130	51	[illegible]770		7.2	21600	"	87	
6	M	1.368	24	12	"	7.6	3130	160	51	[illegible]180		7.4	21600	"	86	
7	Tu	1.[illegible]73	12	24	"	7.5	2530	130	51	[illegible]590		7.2	21600	"	86	
8	W	1.209	24	12	"	7.7	2221	115	52	[illegible]930		7.4	21600	"	90	
9	Th	1.227	12	24	"	7.5	2050	110	54	[illegible]180		7.3	21600	"	92	
10	F	1.341	24	12	"	7.5	2200	130	59	[illegible]250		7.2	21600	"	88	
11	Sa	1.353	12	24	"	7.6	3110	170	55	[illegible]190		7.3	21600	"	87	
12	Su	1.332	24	12	"	7.6	3[illegible]50	200	60	[illegible]110		7.4	21600	"	89	
13	M	1.342	12	24	"	7.5	3820	260	68	[illegible]800		7.3	21600	"	88	
14	Tu	1.342	24	12	"	7.3	3210	220	69	[illegible]450		7.1	21600	"	88	
15	W	1.256	12	24	"	7.5	3940	280	71	[illegible]430		7.3	21600	"	94	
16	Th	1.280	24	12	"	7.3	3920	260	69	1[illegible]860		7.1	21600	"	92	
17	F	1.348	12	24	"	7.5	3830	280	73	1[illegible]400		7.2	21600	"	87	
18	Sa	1.328	24	12	"	7.5	3810	2[illegible]	73	[illegible]300		7.2	21600	"	89	
19	Su	1.290	12	24	"	7.6	3860	270	70	1[illegible]240		7.3	21600	"	91	
20	M	1.395	24	12	"	7.2	3020	220	71	1[illegible]300		7.2	21600	"	86	
21	Tu	1.366	12	24	"	7.1	3860	250	65	[illegible]270		7.4	21600	"	86	
22	W	1.323	24	12	"	7.2	3400	220	65	9800		7.4	21600	"	89	
23	Th	1.385	12	24	"	7.5	2380	170	71	10260		7.4	21600	"	85	
24	F	1.446	24	12	"	7.4	2700	150	56	8560		7.7	21600	"	82	
25	Sa	1.209	12	24	"	7.6	2580	170	66	8970		7.5	21600	"	98	
26	Su	1.289	24	12	"	7.4	2820	170	67	8[illegible]50		7.5	21600	"	91	
27	M	1.424	12	24		7.6	[illegible]20	230	70	8[illegible]		7.5	21600	"	83	
28	Tu	1.306	24	12		7.7	2970	200	67	8470		7.4	21600	"	90	
29	W	1.305	12	24	"	7.7	2820	190	67	8120		7.4	21600	"	90	
30	Th	1.371	24	12	"	7.6	2480	170	69	2970		7.4	21600	"	86	
31	F	1.385	12	24	"	7.6	2530	170	67	7640		7.3	21600	"	85	
Total		41.5	540	540	20.4	232.1	93531	5795	1963	272790		227.1	663300	36.58	2737	
Avg.		1.337	18	18	0.680	7.5	3017	193	63	8800		7.3	21397	1.18	88	
Max.		1.446	24	24	0.680	7.8	3940	280	73	10860		7.7	21600	1.18	98	
Min.		1.209	12	12	0.680	7.1	2050	110	51	5930		7.0	15300	1.18	82	

MONTH OF DEC 76

ANALYTICAL DATA No. 6
SLUDGE DIGESTION

DATE	DAY	TOTAL Solids %					Vol. Solids %					PH		Vol. Acids Mg/L		Alkalinity Mg/L	
		Raw Sludge	Prim Bot.	Prim. Super	Sec Bot.	Sec. Super	Raw Sludge	Prim Bot.	Prim Super	Sec. Bot.	Sec. Super	Prim.	Sec.	Prim	Sec.	Prim.	Sec.
1	W			1.3	6.0	0.4											
6	M	2.9	7.0	1.4	6.6	0.7	67	43	49	40	47	7.0	7.0	300	210	3050	2870
13	M			1.0		0.5						7.0	7.1				
16	Th	3.0		1.2	6.8							7.0		205		2425	
20	M			1.0		0.3											
22	W					0.6											
21	W	2.4		1.4		0.5						7.0	7.0				
TOTAL		8.3	7.0	7.3	19.4	3.0	67	43	49	40	47	28.0	21.1	505	210	5475	2870
Avg.		2.8	7.0	1.2	6.5	0.5	67	43	49	40	47	7.0	7.0	253	210	2738	2870
Max.		3.0	7.0	1.4	6.8	0.7	67	43	49	40	47	7.0	7.1	300	210	3050	2870
Min.		2.4	7.0	1.0	6.0	0.3	67	43	49	40	47	7.0	7.0	205	210	2425	2870

TOTAL GALLONS DIGESTED SLUDGE HAULED TO DRYING BEDS 96,000 Vol. Red. Prim = 63% Sec = 31%

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of *DEC* 19*76*

PLANT OPERATING DATA

Sheet No. 5

DATE	DAY	SLUDGE, GALLONS					TEMP. °F		SLUDGE CIRC., hrs.		GAS PRODUCED 1000 CU FT		UTILITIES				
		SCUM SUMP PUMP	RAW SLUDGE PUMP	prim. DIG TO BEDS	sec. DIG TO beds		DIG NO. 1	DIG NO. 2	DIG NO. 1	DIG NO. 2	DIG NO. 1	DIG NO. 2	ELECT POWER KW HRS	NAT. GAS 1000 CU FT			
1	W	2253	18400	0	18000		95		2				2240	108			
2	Th	1087	17800	0	0		95						2160	107			
3	F	3400	18096	0	0		96		2				2240	101			
4	Sa	1146	18113	0	0		96						2240	101			
5	Su	1447	18096	0	0		96		2				2240	100			
6	M	753	18826	0	0		96						2240	98			
7	Tu	840	18835	0	18000		96		2				2400	98			
8	W	1433	17904	0	0		96						2400	99			
9	Th	240	18339	0	18000		96		2				2320	97			
10	F	900	18139	0	0		96						2400	99			
11	Sa	1213	18096	0	0		96		2				2400	98			
12	Su	1287	18104	0	0		96						2400	100			
13	M	287	18157	0	12000		96		2				2480	99			
14	Tu	1460	18130	0	0		96						2560	99			
15	W	1120	18209	0	0		96		2				2400	100			
16	Th	220	18113	0	15000		96						2480	101			
17	F	1107	18861	0	0		96		2				2480	102			
18	Sa	1567	18113	0	0		96						2480	102			
19	Su	774	18096	0	0		96		2				2640	102			
20	M	1213	18112	0	0		96						2560	97			
21	Tu	1313	18122	0	15000		96		2				2560	100			
22	W	1093	18748	0	0		96						2560	100			
23	Th	933	18174	0	0		96		2				2560	101			
24	F	1060	18072	0	0		96						2560	101			
25	Sa	1380	18122	0	0		96		2				2460	103			
26	Su	1220	18122	0	0		96						2560	103			
27	M	1458	18487	0	0		96		2				2480	101			
28	Tu	2700	18000	0	0		96						2720	106			
29	W	1339	18113	0	0		96		2				2560	107			
30	Th	1120	18000	0	0		96						2480	103			
31	F	1500	18000	0	0		96		2				2720	103			
TOTAL		46683	565006		96000		2974		34				76060	3138			
AVERAGE		1506	18226		16000		96		1.1				2454	101			
MAXIMUM		2700	18748		18000		96		2				2720	108			
MINIMUM		753	17800		12000		95		2				2160	97			

Month of DEC 1976

WEEKLY H_2S RESULTS IN AIR SHEET No. 7

STATION No.	PLANT PERIMETER: Tag on Date + Time	Tag off Date + Time	Elapsed Time Days	Color Grade	H_2S mg/L	STATION No.	SLUDGE DRYING BEDS: Tag on Date + Time	Tag off Date + Time	Elapsed Time Days	Color Grade	H_2S mg/L
1	11/28@0830	12/5@0830	7	1.00	0.00071	L-2	11/28@0800	12/5@0800	7	<0.25	<0.00020
2	"	"	"	1.00	0.00071	L-4	"	"	"	"	"
3	"	"	"	1.00	0.00071	L-6	"	"	"	"	"
4	"	"	"	<0.25	<0.00020	L-8	"	"	"	"	"
1	12/6@0830	12/13@1130	7	1.00	0.00071	L-2	12/6@0800	12/13@0800	7	<0.25	<0.00020
2	"	"	"	1.00	0.00071	L-4	"	"	"	"	"
3	"	"	"	1.00	0.00071	L-6	"	"	"	"	"
4	"	"	"	<0.25	<0.00020	L-8	"	"	"	"	"
1	12/13@1130	12/20@0800	7	2.00	0.00196	L-2	12/13@0800	12/20@0800	7	<0.25	<0.00020
2	"	"	"	2.00	0.00196	L-4	"	"	"	"	"
3	"	"	"	1.00	0.00071	L-6	"	"	"	"	"
4	"	"	"	<0.25	<0.00020	L-8	"	"	"	"	"
1	12/20@0800	12/27@0800	7	0.50	0.00042	L-2	12/20@0800	12/27@0800	7	<0.25	<0.00020
2	"	"	"	0.25	0.00020	L-4	"	"	"	"	"
3	"	"	"	1.00	0.00071	L-6	"	"	"	"	"
4	"	"	"	<0.25	<0.00020	L-8	"	"	"	"	"
1	12/27@0800	1/3@0800	7	<0.25	<0.00020	L-2	12/27@0800	1/3@0800	7	<0.25	<0.00020
2	"	"	"	"	"	L-4	"	"	"	"	"
3	"	"	"	"	"	L-6	"	"	"	"	"
4	"	"	"	"	"	L-8	"	"	"	"	"
Total			35	12.75	0.01022				35	<0.25	<0.00020
Avg.			7	0.36	0.00029				7	<0.25	<0.00020
High			7	2.00	0.00196				7	<0.25	<0.00020
Low			7	<0.25	<0.00020				7	<0.25	<0.00020

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of Feb 1979

WEATHER AND FLOW DATA

DATE	DAY	WEATHER DATA					SEWAGE FLOW								Raw Infl. Lims [illegible] lbs/day
		TEMP. °F		PRECIPITATION	EVAPORATION	[illegible] WIND DIRECTION & M.P.H.	MILLION GALLONS						EFFL. RATE MGD		
							INFLUENT M.G.D.	EFFLUENT							
		MAX.	MIN	INCHES	INCHES			TOTAL M.G.D	100 acre	62 acre	37 acre		MAX.	MIN.	
1		56	34			W@5		1.225	0.691	0.650	1.035		2.6	0.1	1050
2		52	32			N@5		1.274	0.62[illegible]	0.550	0.368		"	"	1000
3		56	32			NE@4		1.124	0.635	0.550	0.368		"	"	800
4		62	32			NE@7		1.244	0.59[illegible]	0.550	0.368		"	"	700
5		62	34			W@2		1.238	0.62[illegible]	0.600	0.368		"	"	800
6		64	38			W@0		1.213	0.713	0.700	0.368		"	"	1100
7		62	47			N@4		1.304	0.605	0.600	0.320		"	"	1150
8		60	42	0.05		SW@10		1.191	0.705	0.691	0.288		"	"	950
9		62	42	0.19		W@5		1.225	0.622	0.600	0.320		"	"	1000
10		66	32			W@2		1.141	0.491	0.550	0.320		"	"	1000
11		68	33			E@3		1.175	0.595	0.500	0.368		"	"	850
12		70	32			SE@5		1.124	0.700	0.624	0.352		"	"	1050
13		75	32			NE@8		1.180	0.650	0.600	0.368		"	"	1000
14		76	40			NW@2		1.263	0.400	0.463	0.391		"	"	750
15		72	40			S@2		1.133	0.633	0.600	0.414		"	"	950
16		74	40			NE@1		1.142	0.548	0.500	0.414		"	"	1300
17		74	37			SW@3		1.138	0.588	0.550	0.414		"	"	1200
18		75	40			S@2		1.182	0.592	0.590	0.414		"	"	1300
19		70	40			S@1		1.124	0.574	0.550	0.414		"	"	1100
20		58	46			S@3		1.050	0.600	0.552	0.414		"	"	1000
21		60	37	0.47		E@5		1.251	0.551	0.500	0.414		"	"	1100
22		60	32	0.16		SE@6		1.190	0.600	0.590	0.396		"	"	1100
23		58	38	0.11		NW@12		1.152	0.600	0.752	0.414		"	"	1000
24		56	34	0.06		N@10		1.107	0.600	0.607	0.414		"	"	900
25		60	32			SW@2		1.176	0.500	0.576	1.035		"	"	1000
26		64	40			SW@3		1.156	0.600	0.556	1.035		"	"	1050
27		65	37			S@3		1.145	0.595	0.550	0.945		"	"	1150
28		58	36			W@10		1.180	0.700	0.680	1.035		"	"	1100
29															
30															
31															
TOTAL		1801	1062	1.04		12.5		33.163	16,924	16,439	13,774		72.8	2.8	29750
AVERAGE		64	38	0.04		5		1.184	0.604	0.587	0.492		2.6	0.1	1027
MAXIMUM		75	47	0.47		12		1.304	0.713	0.752	1.035		2.6	0.1	1300
MINIMUM		52	32	<0.01		0		1.050	0.400	0.463	0.288		2.6	0.1	700

Monthly Analytical Data Sheet No. 1

FEB 71

Date	Day	Sampling Hours	5 Day B.O.D. mg/l				Sus. Solids mg/l				Total Solids				Total Dissolved Sol.			
			Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.
2	W	24	180	116	17	—	216	74	19	—	—	—	—	—	—	—	—	—
9	W	24	164	96	18	—	220	48	7	—	951	819	722	—	731	771	715	—
17	Th	24	243	138	34	—	368	48	18	—	1133	811	755	—	765	763	737	—
23	W	24	281	180	38	—	208	48	17	—	1019	826	816	—	811	778	799	—
Total			868	530	107		1012	218	61		3103	2456	2293		2307	2312	2251	
Avg.			217	133	27		253	55	15		1034	819	764		769	771	750	
Max			281	180	38		368	74	19		1133	826	816		811	778	799	
Min			164	96	17		208	48	7		951	811	722		731	763	715	

FE 17

Monthly Analytical Data Sheet No. 2

DATE	DAY	SAMPLING HOURS	SETTLEABLE SOL. ml/L				HYDROGEN ION PH				AMMONIA "N" mg/L		NITRATE "N" mg/L		L.A.S. mg/L	CL2 mg/L	FLUORIDE mg/L
			RAW	PRIM.	SECONDARY	OXID. POND II	RAW	PRIM.	SECONDARY	OXID. POND II	PRIM.	SECONDARY	SECONDARY	OXID. POND II	SECONDARY	SECONDARY	SECONDARY
2	W	24	—	—	—	—	8.6	8.2	7.9	—	—	—	—	—	—	—	—
9	W	24.	8.0	<0.1	<0.1	—	8.4	8.0	7.6	—	—	—	—	—	—	<0.1	1.3
17	Th	24	12.5	0.1	<0.1	—	8.8	8.5	7.9	—	—	—	—	—	—	<0.1	0.98
23	W	24	11.0	<0.1	<0.1	—	8.5	8.2	8.0	—	—	—	—	—	—	<0.1	0.86
TOTAL			31.5	0.1	<0.1		34.3	32.9	31.4							<0.1	3.14
AVG.			10.5	<0.1	<0.1		8.6	8.2	7.9							<0.1	1.05
MAX.			12.5	0.1	<0.1		8.8	8.5	8.0							<0.1	1.30
MIN.			8.0	<0.1	<0.1		8.4	8.0	7.6							<0.1	0.86

FEB 79

MONTH - YEAR	Flow	Time	Station E-1			Station EP-1	Station EP-2								
DATE	Rate M.G.	of Sampling	D.O. mg/L	Dis. H2S mg/L	pH	D.O. mg/L	D.O. mg/L	Dis. H2S mg/L	Sat. Sol. ml/L						
1	[illegible]	[illegible]	.3	[illegible]	[illegible]	[illegible]	11.1	[illegible]	[illegible]						
2	1.8	1730	.3	<0.1	7.3	7.9	9.0	<0.1	<0.1						
3	1.7	1630	.5	<0.1	7.6	8.5	12.1	<0.1	<0.1						
4	1.8	1630	.5	<0.1	7.1	8.1	16.2	<0.1	<0.1						
5	1.7	1630	.4	<0.1	7.2	8.2	11.4	<0.1	<0.1						
6	1.8	1630	.3	<0.1	7.3	8.3	10.6	<0.1	<0.1						
7	1.7	1630	.3	<0.1	7.6	8.4	12.6	<0.1	<0.1						
8	1.7	1630	.4	<0.1	7.6	8.6	[illegible]	<0.1	<0.1						
9	1.6	1630	.4	<0.1	7.35	8.6	[illegible]	<0.1	<0.1						
10	1.2	1630	.3	<0.1	[illegible]	8.4	13.8	<0.1	<0.1						
11	1.5	1630	.3	<0.1	7.5	8.3	[illegible]	<0.1	<0.1						
12	1.5	1630	.2	<0.1	7.5	9.2	11.0	<0.1	<0.1						
13	1.4	1645	.3	<0.1	7.5	7.6	11.5	<0.1	<0.1						
14	1.4	1630	.2	<0.1	7.4	9.0	15.0	<0.1	<0.1						
15	1.4	1630	.4	<0.1	7.5	9.2	15.0	<0.1	<0.1						
16	1.3	1630	.3	<0.1	7.6	9.4	14.8	<0.1	<0.1						
17	1.4	1630	.4	<0.1	7.7	9.0	15.4	<0.1	<0.1						
18	1.4	1630	.2	<0.1	7.8	9.4	16.0	<0.1	<0.1						
19	1.4	1715	.5	<0.1	7.6	8.8	16.0	<0.1	<0.1						
20	1.3	1630	.6	<0.1	7.7	9.0	10.0	<0.1	<0.1						
21	1.4	1630	.6	<0.1	7.6	9.2	15.6	<0.1	<0.1						
22	1.0	17:00	.8	<0.1	7.7	8.8	14.0	<0.1	<0.1						
23	1.2	17:00	.4	<0.1	7.5	8.4	13.2	<0.1	<0.1						
24	.6	17:00	.6	.2	7.3	8.2	11.2	<0.1	<0.1						
25	1.1	17:00	.6	<0.1	7.4	8.6	11.6	<0.1	<0.1						
26	1.6	16:30	.8	<0.1	7.3	8.0	11.8	<0.1	<0.1						
27	1.4	16:30	.8	<0.1	7.3	8.6	12.4	<0.1	<0.1						
28	1.3	1630	.5	<0.1	7.5	8.0	12.2	<0.1	<0.1						
~~29~~															
~~30~~															
~~31~~															
Total	40.8	46120	12.5	0.2	[illegible]	237.6	347.4	<0.1	<0.1						
Max.	1.8	1700	0.8	0.2	7.8	9.4	16.0	<0.1	<0.1						
Min.	0.6	1630	0.2	<0.1	7.1	6.9	9.0	<0.1	<0.1						
Avg.	1.457	1647	0.5	<0.1	7.5	8.5	12.4	<0.1	<0.1						

PLEASANTON WATER [illegible]

Month of Feb 1977

Monthly Analytical Data Sheet No. 4
Activated Sludge

			Bio-Aerators Flow Rs			Mixed Liquor Bio-Samp No. II				R.A.S. Bio-Aeration Tank						
Date	Day	Flow Factor	No. N6 Hours On	No. 147 Hours On	Million G.P.D.	Avg pH	Avg Sus. Sol.	Avg Set. Sol.	Avg SVI	Avg Sus. Sol.	Avg. D.O.	Avg pH	Waste R.A.S.	R.A.S. MGD	% Return	% Ash
1	Tu	1.225	12	24	0.680	7.5	3300	210	64	6410		7.1	21600	1.18	96	
2	W	1.294	24	12	"	7.3	2560	200	78	6620		7.0	"	"	92	
3	Th	1.184	12	24	"	7.6	2720	180	66	6550		7.2	"	"	100	
4	F	1.244	24	12	"	6.8	2700	190	70	6380		7.5	"	"	95	
5	Sa	1.228	12	24	"	7.4	2420	160	66	7180		6.8	"	"	96	
6	Su	1.213	24	12	"	7.6	2690	170	63	7790		7.0	"	"	97	
7	M	1.304	12	24	"	7.5	3150	210	67	8410		7.1	"	"	90	
8	Tu	1.191	24	12	"	7.6	2892	190	66	7990		7.2	"	"	99	
9	W	1.225	12	24	"	7.5	3524	235	67	8900		7.2	"	"	96	
10	Th	1.141	24	12	"	7.5	3420	230	67	8130		7.2	"	"	103	
11	F	1.175	12	24	"	7.5	3056	190	62	9170		7.2	"	"	100	
12	Sa	1.184	24	12	"	7.5	2892	190	66	8180		7.2	"	"	100	
13	Su	1.120	12	24	"	7.5	3028	200	66	8130		7.2	"	"	100	
14	M	1.263	24	12	"	7.4	2668	160	60	8150		7.2	"	"	93	20
15	Tu	1.133	12	24	"	7.5	2880	160	56	7700		7.3	"	"	104	
16	W	1.148	24	12	"	7.6	2272	130	57	5140		7.3	"	"	103	
17	Th	1.132	12	24	"	7.6	1984	110	55	6400		7.4	"	"	104	
18	F	1.182	24	12	"	7.8	1840	90	49	6140		7.5	"	"	100	
19	Sa	1.124	12	24	"	7.5	1828	90	49	5160		7.3	"	"	105	
20	Su	1.050	24	12	"	7.6	2032	110	54	6000		7.3	19800	"	112	
21	M	1.251	12	24	"	7.5	1856	90	48	5800		7.3	21600	"	94	
22	Tu	1.190	24	12	"	7.5	2312	110	48	6650		7.2	"	"	99	
23	W	1.152	12	24	"	7.4	3124	140	45	6900		7.2	"	"	102	
24	Th	1.107	24	12	"	7.4	3128	170	54	7400		7.2	"	"	110	
25	F	1.176	12	24	"	7.4	2960	170	57	7340		7.2	"	"	100	
26	Sa	1.156	24	12	"	7.3	2960	130	44	7640		7.2	"	"	102	
27	Su	1.145	12	24	"	7.4	2400	180	53	8320		7.2	"	"	102	
28	M	1.180	24	12	"	7.4	3096	205	66	9200		7.2	"	"	100	
~~29~~																
~~30~~																
~~31~~																
Total		33.153	540	540	21.08	209.1	76,692	4600	1663	206080		201.9	603,000	36.58	2794	20
Avg		1.184	18	18	0.680	7.5	2739	164	59	7360		7.2	21,536	1.18	100	20
Max		1.304	24	24	0.680	7.8	3524	235	78	9200		7.5	21,600	1.18	112	20
Min		1.050	12	12	0.650	6.8	1828	90	44	5800		6.8	19,800	1.18	92	20

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of *Feb* 1977

PLANT OPERATING DATA

DATE	DAY	SLUDGE, GALLONS					TEMP. °F		SLUDGE CIRC. hrs.		GAS PRODUCED 1000 CU FT		UTILITIES				
		SCUM SUMP PUMP	RAW SLUDGE PUMP	prim. DIG TO BEDS	sec. DIG TO beds		DIG NO.1	DIG NO.2	DIG NO.1	DIG NO.2	DIG NO.1	DIG NO.2	ELECT POWER KW HRS	NAT. GAS 1000 CU FT			
1	Tu	1233	18383				95		2				2480	102			
2	W	840	17870				95						2400	103			
3	Th	1413	18461		15000		95		2				2400	103			
4	F	1367	18078		15000		95						2480	105			
5	Sa	1187	18435				95		2				2480	102			
6	Su	1160	17794				96						2480	101			
7	M	1527	18965				96		2				2400	97			
8	Tu	1390	18067				92						2480	47			
9	W	1387	18078				92		2				2400	104			
10	Th	1173	18096				92						2420	107			
11	F	1920	18104				94		2				2400	102			
12	Sa	1807	18452				94						2400	100			
13	Su	1240	18852				94		2				2320	100			
14	M	1000	18853		15000		96						2400	97			
15	Tu	1420	18165	3000	12000		96		2				2400	97			
16	W	1506	14991				96						2400	98			
17	Th	1127	18365				96		2				2240	92			
18	F	1220	18582				96						2320	95			
19	Sa	1160	18852				96		2				2160	96			
20	Su	1606	18095				96						2240	95			
21	M	1460	18087				96		2				2400	97			
22	Tu	1540	18104				95						2400	100			
23	W	1785	18060				95		2				2320	100			
24	Th	1340	18104		24000		96						2320	102			
25	F	1346	18086				96		2				2320	110			
26	Sa	1106	18075				96						2400	111			
27	Su	1953	18087				96		2				2320	101			
28	M	1253	18748				96						2240	96			
~~29~~																	
~~30~~																	
~~31~~																	
TOTAL		38366	508695	3000	81000		2663		28				66560	2746			
AVERAGE		1370	18169				95		2				2377	98			
MAXIMUM		1953	18852				96		2				2480	111			
MINIMUM		840	14991				92		2				2240	47			

ANALYTICAL DATA No. 5
Sludge Digestion

Date	Day	Total Solids %					Vol. Solids %					PH		Vol. Acids mg/L		Alkalinity mg/L	
		Raw Sludge	Prim. Bot.	Prim. Supn.	Sec. Bot.	Sec. Supn.	Raw Sludge	Prim. Bot.	Prim. Supn.	Sec. Bot.	Sec. Supn.	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
3	Th			1.0		0.5											
15	Tu	2.1	7.0	0.9	7.9	0.2	74	42	48	46	49	7.4	7.5	160	100	2685	3100
26	F			1.4		0.4											
Total		2.1	7.0	3.3	7.9	1.1	74	42	48	46	49	7.4	7.5	160	100	2685	3100
Avg.		2.1	7.0	1.1	7.9	0.4	74	42	48	46	49	7.4	7.5	160	100	2685	3100
Max.		2.1	7.0	1.4	7.9	0.5	74	42	48	46	49	7.4	7.5	160	100	2685	3100
Min.		2.1	7.0	0.9	7.9	0.2	74	42	48	46	49	7.4	7.5	160	100	2685	3100

Total Gallons Digested Sludge Hauled To Drying Beds 24,000 Vol. Red. Prim = 75% Sec = 8%

WEEKLY. H_2S. RESULTS IN AIR. SHEET No. 6

STATION No.	PLANT PERIMETER					STATION No.	SLUDGE DRYING BEDS				
	TAG ON DATE + TIME	TAG OFF DATE + TIME	ELAPSED TIME DAYS	COLOR GRADE	H_2S mg/L		TAG ON DATE + TIME	TAG OFF DATE + TIME	ELAPSED TIME DAYS	COLOR GRADE	H_2S mg/L
1	1/31@0800	2/7@0800	7	<0.25	<0.00020	L-2	1/31@0800	2/7@0800	7	<0.25	<0.00020
2	"	"	"	"	"	L-4	"	"	"	"	"
3	"	"	"	"	"	L-6	"	"	"	"	"
4	"	"	"	"	"	L-8	"	"	"	"	"
1	2/7@0800	2/14@0800	7	<0.25	<0.00020	L-2	2/7@0800	2/14@0800	7	<0.25	<0.00020
2	"	"	"	"	"	L-4	"	"	"	"	"
3	"	"	"	"	"	L-6	"	"	"	"	"
4	"	"	"	"	"	L-8	"	"	"	"	"
1	2/14@0800	2/22@0830	8	<0.25	<0.00020	L-2	2/14@0800	2/21@0800	7	<0.25	<0.00020
2	"	"	"	"	"	L-4	"	"	"	"	"
3	"	"	"	"	"	L-6	"	"	"	"	"
4	"	"	"	"	"	L-8	"	"	"	"	"
1	2/22@0800	2/28@0800	6	<0.25	<0.00020	L-2	2/21@0800	2/28@0800	7	<0.25	<0.00020
2	"	"	"	"	"	L-4	"	"	"	"	"
3	"	"	"	"	"	L-6	"	"	"	"	"
4	"	"	"	"	"	L-8	"	"	"	"	"
Total											
Avg.											
High											
Low											

Month Feb 1977

Additional Comments

Average percentage reductions for the month:

	Primary Effl.	Sec. Clar. Effl.
B.O.D.	39%	88%
Sus. Sol.	78%	94%

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of [illegible] 1977

WEATHER AND FLOW DATA

DATE	DAY	WEATHER DATA					SEWAGE FLOW								Raw Infl. Lime [illegible] lbs/Day
		TEMP. °F		PRECIPITATION	EVAPORATION	1500 hrs. WIND DIRECTION + M.P.H.	MILLION GALLONS						EFFL. RATE MGD		
							INFLUENT M.G.D.	EFFLUENT							
		MAX.	MIN.	INCHES	INCHES			TOTAL M.G.D	100 acre	62 acre	37 acre		MAX.	MIN.	
1		54	32	0.02		NW 2		1.132	0.482	0.450	1.035		2.6	0.1	1050
2		58	44	0		[illegible]		1.115	0.315	0.500	0.371		"	"	1050
3		[illegible]	42	0		[illegible] 13		1.022	0.648	0.550	0.362		"	"	1050
4		64	32	0		NE 12		1.199	0.549	0.450	0.368		"	"	1050
5		68	34	0		SE 3		1.157	0.607	[illegible]	0.352		"	"	[illegible]
6		[illegible]	38	0		SW 15		[illegible]	[illegible]	[illegible]	0.252		"		[illegible]
7		[illegible]	40	0		W 1		[illegible]	0.677	0.600	0.368		"	"	[illegible]
8		[illegible]	50	0.15		[illegible]		[illegible]	0.419	[illegible]	[illegible]		"	[illegible]	[illegible]
9		57	32	0.24		W 20		[illegible]	0.618	0.600	0.320		"	[illegible]	[illegible]
10		[illegible]	[illegible]	0		[illegible]		[illegible]	0.524	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
11		[illegible]	41	0		NE 5		1.172	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
12		[illegible]	40	[illegible]		[illegible]		[illegible]	[illegible]	0.55	[illegible]		[illegible]	[illegible]	[illegible]
13		[illegible]	30	[illegible]		[illegible]		[illegible]	0.580	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
14		[illegible]	44	0		[illegible]		[illegible]	0.559	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
15		[illegible]	[illegible]	0		[illegible]		[illegible]	0.575	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
16		[illegible]	[illegible]	1.03		W [illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
17		58	32	0		[illegible]		[illegible]	0.589	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
18		[illegible]	[illegible]	0		N [illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
19		[illegible]	[illegible]	0		[illegible]		[illegible]	0.591	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
20		[illegible]	[illegible]	0		W 1		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
21		[illegible]	40	0		[illegible]		[illegible]	[illegible]	[illegible]	0.492		[illegible]	[illegible]	[illegible]
22		76	34	0		[illegible]		1.097	[illegible]	0.599	[illegible]		[illegible]	[illegible]	[illegible]
23		[illegible]	44	0		[illegible] 14		[illegible]	0.609	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
24		[illegible]	40	[illegible]		S [illegible]		[illegible]	0.514	0.500	[illegible]		[illegible]	[illegible]	[illegible]
25		[illegible]	40	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
26		[illegible]	[illegible]	0		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
27		[illegible]	[illegible]	0		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
28		[illegible]	[illegible]	0		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	1250
29		[illegible]	[illegible]	0		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	1250
30		[illegible]	[illegible]	0		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	1250
31		[illegible]	[illegible]	0		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
TOTAL		1960	1182	1.64		245		35.607	18.483	16.924	15.073		72.8	2.8	34350
AVERAGE		63	38	0.21		8		1.147	0.596	0.546	0.486		2.6	0.1	1108
MAXIMUM		76	44	1.03		20		1.235	0.743	0.766	1.035		2.6	0.1	1250
MINIMUM		54	30	<0.01		1		1.095	0.479	0.450	0.204		2.6	0.1	900

[illegible]

Month of [illegible] 19 77

Monthly Analytical Data Sheet No. 1

Date	Day	Sampling Hours	5 Day B.O.D. mg/l				Sus. Solids mg/l				Total Solids				Total Dissolved Sol.			
			Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.	Raw	Prim.	Sec. Effl.	Oxid. Pond No. II Effl.
1	Tu	24	363	204	22	—	228	56	20	—	1154	883	738	—	926	827	718	—
8	Tu	24	302	141	24	—	268	48	23	—	977	754	715	—	711	706	692	—
17	Th	24	222	123	14	—	188	52	7	—	958	868	766	—	770	816	741	—
22	Tu	24	192	120	17	—	164	34	15	—	894	780	725	—	730	744	710	—
30	W	24	359	—	29	23	176	—	12	10	1276	—	719	785	1176	—	709	775
Total			1478	583	106	23	1024	190	89	10	5261	3285	3657	785	4313	3095	3568	775
Avg.			300	147	21	23	205	48	18	10	1052	821	731	785	863	774	713	775
Max.			363	204	29	23	268	56	23	10	1276	883	766	785	1176	827	744	775
Min.			192	120	14	22	164	34	12	10	894	754	715	785	711	706	692	775

Monthly Analytical Data Sheet No. 2 MARCH 77

			Settleable Sol. ml/l				Hydrogen Ion pH				Ammonia N mg/l		Nitrate N mg/l		L.A.S. mg/l	Cl2 mg/l	Fluoride mg/l
Date	Day	Sampling hours	Raw	Prim.	Secondary	Oxid Pond II	Raw	Prim.	Secondary	Oxid Pond II	Prim.	Secondary	Secondary	Oxid Pond II	Secondary	Secondary	Secondary
1	Tu	24	12.0	0.1	<0.1	—	9.1	8.8	8.3	—	—	—	—	—	—	<0.1	0.92
8	Tu	24	14.0	<0.1	<0.1	—	8.5	8.4	8.1	—	—	—	—	—	—	<0.1	0.25
17	Th	24	12.0	0.1	<0.1	—	9.0	8.7	8.2	—	—	—	—	—	—	<0.1	[illegible]
22	Tu	24	11.0	<0.1	<0.1	—	8.2	8.6	8.1	—	—	—	—	—	—	<0.1	0.68
30	W	24	13.0	—	<0.1	<0.1	7.7	—	8.[illegible]	8.4	—	—	—	—		<0.1	0.90
Total			62.0	0.2	<0.1	<0.1	43.1	34.5	41.0	8.4						<0.1	3.14
Avg			12.4	<0.1	<0.1	<0.1	8.6	8.6	8.2	8.4						<0.1	0.63
Max			14.0	0.1	<0.1	<0.1	9.1	8.8	8.3	8.4						<0.1	0.92
Min			11.0	<0.1	<0.1	<0.1	7.7	8.4	8.1	8.4						<0.1	0.62

Grab Samples - Daily [illegible] March 1977

MONTH YEAR DATE	Flow Rate M.G.	Time of Sampling	Station E-1 D.O. mg/L	Station E-1 Dis. H2S mg/L	Station E-1 pH	Station EP-1 D.O. mg/L	Station EP-2 D.O. mg/L	Station EP-2 Dis. H2S mg/L	Station EP-2 Set. Sol. ml/L						
1	[illegible]	1630	0.4	<0.1	8.0	7.6	10.6	<0.1	<0.1						
2	1.5	1630	0.4	<0.1	8.0	7.8	17.4	<0.1	<0.1						
3	[illegible]	1630	[illegible]	<0.1	7.8	7.6	10.4	<0.1	<0.1						
4	[illegible]	1630	0.6	<0.1	7.9	8.8	10.6	<0.1	<0.1						
5	1.3	1630	0.3	<0.1	8.4	7.8	10.0	<0.1	<0.1						
6	[illegible]	1630	0.2	<0.1	8.1	[illegible]	10.6	<0.1	<0.1						
7	1.7	1700	[illegible]	<0.1	[illegible]	7.4	[illegible]	<0.1	[illegible]						
8	[illegible]	1700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
9															
10	1.1	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]							
11	1.5	[illegible]	[illegible]	<0.1	[illegible]	7.3	[illegible]	[illegible]	[illegible]						
12	[illegible]			[illegible]		[illegible]	[illegible]								
13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.7	[illegible]	[illegible]	[illegible]						
14	[illegible]	1730	[illegible]	<0.1	[illegible]	[illegible]	[illegible]	<0.1	<0.1						
15	[illegible]	[illegible]	0.3	[illegible]	7.8	[illegible]	[illegible]	[illegible]							
16	[illegible]	1730	[illegible]	<0.1	[illegible]	8.5	[illegible]	<0.1	[illegible]						
17		1730	[illegible]	<0.1	[illegible]	[illegible]	[illegible]	<0.1	[illegible]	[illegible]					
18	[illegible]	[illegible]	[illegible]	<0.1	8.1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] only @ EP-2					
19	[illegible]	[illegible]	[illegible]	<0.1	[illegible]	[illegible]	[illegible]	<0.1	<0.1						
20	2.0	1730	0.4	<0.1	7.5	7.5	14.7	<0.1	<0.1						
21															
22															
23															
24															
25															
26															
27			[illegible]			[illegible]	[illegible]								
28	1.3	1630	0.3	<0.1	8.0	8.0	16.6	<0.1	<0.1						
29	1.3	1630	0.4	<0.1	8.1	8.8	20.0	<0.1	<0.1						
30	1.3	[illegible]	0.4	<0.1	[illegible]	9.0	[illegible]	<0.1	<0.1						
31	1.2	1630	0.3	<0.1	7.0	10.0	[illegible]	<0.1	<0.1						
Total	45.6	52540	10.8	<0.1	246.3	246.4	419.7	<0.1	<0.1						
Max.	2.4	1730	0.6	<0.1	8.4	10.0	22.8	<0.1	<0.1						
Min.	0.8	1630	0.2	<0.1	7.3	7.0	9.8	<0.1	<0.1						
Avg.	1.47	1700	0.4	<0.1	8.0	8.0	13.5	<0.1	<0.1						

[illegible]

Month of March 1977

Monthly Analytical Data Sheet No. 4

Activated Sludge

Date	Day	Plant Flow	Bio-Aerator [illegible] No. 146 Hours On	Bio-Aerator [illegible] No. 147 Hours On	Million C.F.D.	Mixed Liquor Bio-Sump No. II Avg pH	Mixed Liquor Bio-Sump No. II Avg Sus. Sol.	Mixed Liquor Bio-Sump No. II Avg Set. Sol.	Mixed Liquor Bio-Sump No. II Avg SVI	R.A.S. Avg Sus. Sol.	Bio-Aeration Tank Avg D.O.	Bio-Aeration Tank Avg pH	Waste R.A.S.	R.A.S. M.G.D.	% Return	% Ash
1	Tu	1.132	12	24	0.680	7.9	3400	215	63	15520		7.6	21600	1.18	104	—
2	W	1.115	24	12	"	8.0	3284	220	67	9120		N.D.	"	"	106	
3	Th	1.098	12	24	"	7.6	3008	260	86	9260		7.7	"	"	107	
4	F	1.199	24	12	"	7.9	3540	200	57	11350		7.8	"	"	98	
5	Sa	1.127	12	24	"	7.8	3416	200	59	10060		N.D.	"	"	102	
6	Su	1.122	24	12	"	8.0	3476	210	60	9290		7.8	"	"	105	
7	M	[illegible]	12	24	"	7.8	3512	220	63	8550		7.6	"	"	100	
8	Tu	[illegible]	24	12	"	7.9	2984	190	64	7620		7.7	"	"	105	
9	W	1.118	12	24	"	7.7	2944	200	68	7510		8.0	"	"	105	
10	Th	[illegible]	24	12	"	7.8	3456	210	61	7900		8.0	"	"	112	
11	F	1.178	12	24	"	7.7	2192	120	55	6410		7.5	"	"	100	
12	Sa	[illegible]	24	12	"	8.0	2648	150	57	7040		7.8	"	"	102	
13	Su	[illegible]	12	24	"	8.0	2328	140	60	[illegible]		7.7	"	"	105	
14	M	1.119	24	12	"	7.5	2544	135	53	[illegible]		7.6	"	"	100	
15	Tu	[illegible]	12	24	"	7.4	3264	130	40	5300		7.5			105	22
16	W	1.112	24	12	"	7.5	2084	110	53	5120		7.3			102	
17	Th	1.109	12	24	"	7.7	1688	100	59	5830		7.4	"	"	106	
18	F	1.213	24	12	"	7.5	2748	100	36	6110		7.6	"	"	97	
19	Sa	1.191	12	24	"	7.9	2848	100	35	5310		7.6	"	"	99	
20	Su	1.179	24	12	"	8.0	3464	100	29	5750		7.8	"	"	100	
21	M	1.152	12	24	"	7.9	2600	150	58	6790		7.6	"	"	102	
22	Tu	1.099	24	12	"	7.8	2172	125	58	5710		7.6	"	"	107	
23	W	1.107	12	24	"	8.1	2516	150	60	6690		7.7	"	"	110	
24	Th	1.118	24	12	"	8.0	2288	140	61	5840		7.7	"	"	97	
25	F	1.132	12	24	"	8.0	[illegible]	140	62	[illegible]		[illegible]	"	"	104	
26	Sa	1.170	24	12	"	8.2	[illegible]	[illegible]	59	[illegible]		7.5	"	"	101	
27	Su	1.141	12	24	"	8.2	2156	140	65	[illegible]		7.8	"	"	103	
28	M	[illegible]	24	12	"	7.9	[illegible]	[illegible]	[illegible]	[illegible]		7.7	"	"	101	
29	Tu	[illegible]	12	24	"	7.5	[illegible]	150	66	[illegible]		7.7	"	"	107	
30	W	[illegible]	24	12	"	8.0	3020	180	60	6890		8.1	"	"	104	
31	Th	[illegible]	12	24	"	7.7	3640	220	60	[illegible]		7.9	"	"	105	
Total		35.617	552	564	21.08	243.9	86224	4995	1804	230880		215.6	669600	36.58	3201	22
Avg		1.147	17.8	18.2	0.680	7.9	2781	161	58	7448		7.7	21600	1.18	103	22
Max		1.235	24	24	0.680	8.2	3640	260	86	15520		8.0	21600	1.18	112	22
Min		1.095	12	12	0.680	7.4	1688	100	29	5470		7.3	21600	1.18	97	22

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of March 1977

PLANT OPERATING DATA

DATE	DAY	SLUDGE, GALLONS					TEMP. °F		SLUDGE CIRC. hrs.		GAS PRODUCED 1000 CU FT		UTILITIES				
		SCUM SUMP PUMP	RAW SLUDGE PUMP	prim. DIG TO BEDS	sec. DIG TO beds		DIG NO. 1	DIG NO. 2	DIG NO. 1	DIG NO. 2	DIG NO. 1	DIG NO. 2	ELECT POWER KW HRS	NAT. GAS ~~1000~~ CU FT			
1		1,047	18,076				96		2				2320	101			
2		1,393	18,687				96						2250	101			
3		1,033	18,043				96		2				2240	99			
4		1,953	18,287				96						2240	100			
5		1,360	19,035				96		2				2400	101			
6		1,360	18,687				96						2240	97			
7		1,353	18,165	6,000	18,000		96		2				2240	96			
8		1,353	18,591				96						2240	96			
9		1,213	18,304				96		2				2400	96			
10		980	[illegible]		24,000		[illegible]						2320	101			
11		1,220	18,687				96		2				2320	101			
12		967	18,113				96						[illegible]	96			
13		941	18,506				[illegible]		2				[illegible]	103			
14		993	18,091				[illegible]						[illegible]	[illegible]			
15		1,067	[illegible]		24,000		[illegible]		2				2480	99			
16		906	[illegible]				[illegible]						2400	101			
17		853	18,037				96		2				[illegible]	101			
18		1,260	18,026				95						2320	100			
19		1,093	18,058				[illegible]		2				2320	[illegible]			
20		1,293	[illegible]				96						2320	[illegible]			
21		1,540	19,608				95		2				2320	99			
22		1,307	18,837		18,000		95						2160	92			
23		1,253	18,304	6,000	6,000		95		2				[illegible]	96			
24		1,680	18,617				95						2320	99			
25		1,487	18,087				95		2				[illegible]	99			
26		1,813	18,104				[illegible]						[illegible]	99			
27		1,400	[illegible]				[illegible]		2				[illegible]	99			
28		753	18,991				[illegible]						2240	96			
29		2,220	18,095				[illegible]		2				2480	99			
30		1,427	[illegible]				[illegible]						2420	[illegible]			
31		[illegible]	[illegible]				[illegible]		2				2400	99			
TOTAL		41251	569457	12000	87000		2968		32				72060	3062			
AVERAGE		1331	18370				96		2				2325	99			
MAXIMUM		2293	19678				96		2				2480	103			
MINIMUM		853	17791				95		2				2160	92			

ANALYTICAL DATA No. 5
SLUDGE DIGESTION

MARCH 77

Date	Day	Total Solids %					Vol. Solids %					PH		Vol. Acids mg/L		Alkalinity mg/L	
		Raw Sludge	Prim. Bot.	Prim. Super	Sec. Bot.	Sec. Super	Raw Sludge	Prim. Bot.	Prim. Super	Sec. Bot.	Sec. Super	Prim.	Sec.	Prim.	Sec.	Prim.	Sec.
7	W	1.9	6.6	0.9	6.3	0.2	70	42	51	46	44	7.2	7.1	190	120	2820	3120
22	Tu	2.2	6.5	1.2	6.0	0.1											
Total		4.1	13.1	2.1	12.3	0.3	70	42	51	46	44	7.2	7.1	190	120	2820	3120
Avg.		2.1	6.6	1.1	6.2	0.2	70	42	51	46	44	7.2	7.1	190	120	2800	3120
Max.		2.2	6.6	1.2	6.3	0.2	70	42	51	46	44	7.2	7.1	190	120	2800	3120
Min.		1.9	6.5	0.9	6.0	0.1	70	42	51	46	44	7.2	7.1	190	120	2820	3120

TOTAL GALLONS DIGESTED SLUDGE HAULED TO DRYING BEDS 99000 Vol. Red. Prim = 71% Sec = 18%

MONTH OF March 19[illegible]

WEEKLY H₂S RESULTS IN AIR SHEET No. 6

Station No.	PLANT PERIMETER					Station No.	SLUDGE DRYING BEDS				
	Tag On Date & Time	Tag Off Date & Time	Elapsed Time Days	Color Grade	H_2S mg/L		Tag On Date & Time	Tag Off Date & Time	Elapsed Time Days	Color Grade	H_2S mg/L
1	2/28@[illegible]	3/7 1000	7	<0.25	<0.00020	L-2	2/28@[illegible]	3/7@[illegible]	7	<0.25	<0.00020
2	"	"	"	0.25	0.00020	L-4	"	"	"	"	"
3	"	"	"	0.50	0.00042	L-6	"	"	"	"	"
4	"	"	"	<0.25	<0.00020	L-8	"	"	"	"	"
1	3/7 1000	3/14@0800	7	0.25	0.00020	L-2	3/7@0800	3/14@0800	7	<0.25	<0.00020
2	"	"	"	0.25	0.00020	L-4	"	"	"	"	"
3	"	"	"	0.25	0.00020	L-6	"	"	"	"	"
4	"	"	"	<0.25	<0.00020	L-8	"	"	"	"	"
1	3/14@0800	3/21@0800	7	<0.25	<0.00020	L-2	3/14@0800	3/21@0800	7	<0.25	<0.00020
2	"	"	"	"	"	L-4	"	"	"	"	"
3	"	"		"	"	L-6	"	"	"	"	"
4	"	"	"	"	"	L-8	"	"	"	"	"
1	3/21@0800	3/28@0800	7	<0.25	<0.00020	L-2	3/21@0800	3/28@0800	7	<0.25	<0.00020
2	"	"	"	0.25	0.00020	L-4	"	"	"	"	"
3	"	"	"	0.25	0.00020	L-6	"	"	"	"	"
4	"	"	"	<0.25	<0.00020	L-8	"	"	"	"	"
Total											
Avg											
High											
Low											

Month March 1977

Additional Comments

Average percentage reductions for the month:

	Primary Effl.	Sec. Clar. Effl.
B.O.D.	51%	93%
Sus. Sol.	77%	91%

Industrial discharge monitoring

Villa Armando Winery (Composites)

	3/9-10	3/14-15	3/23-24	3/28-29
Flow(gpd)	N.D.	209	613	45(from water meter)
B.O.D.(mg/L)	1530	4165	990	N.D.
B.O.D.(lbs./Day)	N.D.	7.3	5.1	N.D.
Sus. Sol.(mg/L)	208	636	48	N.D.
Sus. Sol.(lbs./Day)	N.D.	1.1	0.3	N.D.
Total Sol.(mg/L)	1764	3987	944	N.D.
pH(units)	9.4	10.0	7.4	N.D.

Calculated sewer discharge fee = $13.00 for this month

Pleasanton Cheese Factory

	3/29/77(Grab)	3/29-30(10 hr. composite)
Flow(gpd)	N.D.	8415(from water meter)
B.O.D.(mg/L)	7960	6560
B.O.D.(lbs./Day)	N.D.	460
Sus. Sol.(mg/L)	128	1724
Sus,Sol.(lbs./Day)	N.D.	121
Total Sol.(mg/L)	12917	8364
pH(units)	7.1	6.7

Calculated sewer discharge fee = $1680.00 for this month

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of April 1977

WEATHER AND FLOW DATA

DATE	DAY	WEATHER DATA					SEWAGE FLOW								Raw Infl. Lime Usage lbs/day
		TEMP. °F		PRECIPITATION	EVAPORATION	WIND DIRECTION	MILLION GALLONS						EFFL. RATE MGD		
							INFLUENT M.G.D.	EFFLUENT							
		MAX	MIN	INCHES	INCHES			TOTAL M.G.D	100 acre	62 acre	37 acre		MAX.	MIN.	
1	F	65	56	0		SE 2		1.154	0.600	0.554	0.204		2.6	0.1	1300
2	Sa	68	56	0		WE 8		1.125	0.600	0.578	0.180		"	"	1300
3	Su	72	40	0		SWE 3		1.091	0.500	0.591	0.180		"	"	1350
4	M	76	42	0		SE 2		1.179	0.600	0.579	0.180		"	"	1200
5	Tu	76	44	0		[illegible] 1		1.091	0.500	0.591	0.180		"	"	1200
6	W	80	48	0		NE 2		1.068	0.600	0.568	0.192		"	"	1250
7	Th	62	52	0		NWE 5		1.140	0.500	0.440	0.192		"	"	1250
8	F	68	40	0		SWE 5		1.103	0.500	0.600	0.192		"	"	800
9	Sa	74	[illegible]	0.09		WE 2		1.162	0.500	0.560	0.192		"	"	800
10	Su	69	39	0		[illegible]		1.114	0.600	0.514	0.204		"	"	1250
11	M	74	32	0		NWE 8		1.148	0.650	0.598	0.216		"	"	950
12	Tu	81	35	0		WE 2		1.110	0.600	0.510	[illegible]		"	"	850
13	W	70	31	0		SW 12		1.173	0.500	0.598	0.216		"	"	900
14	Th	77	[illegible]	0		WE 2		1.197	0.500	0.497	0.216		"	"	1050
15	F	83	44	0		NWE 10		1.118	0.600	0.518	0.216		"	"	600
16	Sa	72	45	0		WE 2		1.134	0.600	0.534	0.216		"	"	850
17	Su	78	50	0		NE 6		1.138	0.600	0.538	0.216		"	"	800
18	M	73	43	0		NNE 7		1.159	0.700	0.557	0.216		"	"	800
19	Tu	80	40	0		NNE 3		1.128	0.600	0.528	0.216		"	"	900
20	W	79	38	0		WE 1		1.100	0.600	0.600	0.216		"	"	900
21	Th	80	[illegible]	0		WE 1		1.113	0.500	0.413	0.216		"	"	900
22	F	83	42	0		SWE 8		1.214	0.700	0.514	0.540		"	"	900
23	Sa	82	44	0		SE 2		1.117	0.600	0.517	0.540		"	"	1100
24	Su	81	43	0		SE 2		1.114	0.650	0.564	0.540		"	"	1100
25	M	80	54	0		WE 10		1.158	0.650	0.608	0.540		"	"	900
26	Tu	[illegible]	45	0		WE 8		1.097	0.550	0.649	0.540		"	"	900
27	W	[illegible]	40	0		SWE 12		1.104	0.550	0.454	0.204		"	"	1100
28	Th	[illegible]	50	0		SE 6		1.096	0.450	0.446	0.192		"	"	1050
29	F	81	[illegible]	0		[illegible]		1.223	0.700	0.653	0.192		"	"	1500
30	Sa	80	[illegible]	0		NE 3		1.112	0.600	0.512	0.192		"	"	1350
31															
TOTAL		2253	1290	0.29		167		33.955	12.700	16.355	7.752		72.8	3.0	31100
AVERAGE		75	43	<0.01		6		1.132	0.510	0.545	0.258		2.6	0.1	1037
MAXIMUM		83	54	0.09		12		1.223	0.700	0.649	0.540		2.6	0.1	1500
MINIMUM		64	36	0		1		1.091	0.500	0.413	0.180		2.6	0.1	600

PLEASANTON WATER POLLUTION CONTROL PLANT Month of April 1977

MONTHLY ANALYTICAL DATA SHEET No. 1

DATE	DAY	Sampling Hours	5 DAY B.O.D. mg/L				SUS. Solids mg/L				TOTAL Solids				TOTAL Dissolved Sol.			
			RAW	PRIM.	SEC. EFFL.	Oxid. Pond No. II EFFL.	RAW	PRIM.	SEC. EFFL.	Oxid. Pond No. II EFFL.	RAW	PRIM	SEC. EFFL.	Oxid. Pond No. II EFFL.	RAW	PRIM	SEC. EFFL.	Oxid. Pond No. II EFFL.
5	Tu	24	348	167	24	—	204	64	12	—	1006	830	774	—	792	806	762	—
14	Th	24	277	—	27	—	232	—	30	—	982	—	720	—	750	—	690	—
21	Th	24	246	63	17	—	176	42	6	—	1035	930	836	—	857	829	830	—
28	Th	24	216	102	20	—	168	48	10	—	1314	912	900	—	1146	864	896	—
TOTAL			1087	332	88		780	154	58		4337	2672	3230		3547	2558	3172	
Avg.			272	111	22		195	51	15		1084	891	808		887	853	793	
Max			348	167	27		232	64	30		1314	930	900		1146	888	890	
Min			216	63	17		168	42	6		982	830	720		750	806	690	

APRIL '77

Monthly Analytical Data Sheet No. 2

DATE	DAY	Sampling hours	Settleable Sol. ml/l				Hydrogen Ion pH				[illegible] N mg/l		Nitrate N mg/l		L.A.S. mg/l	Cl2 mg/l	[illegible] mg/l
			Raw	Prim.	Secondary	Oxid. Pond II	Raw	Prim.	Secondary	Oxid. Pond II	Prim.	Secondary	Secondary	Oxid. Pond II	Secondary	Secondary	Secondary
5	Tu	24	12.0	<0.1	<0.1	—	7.8	8.6	8.2	—	—	—	—	—	—	<0.1	0.77
14	Th	24	12.5	—	0.1	—	8.6	—	8.0	—	—	—	0.04	—	—	<0.1	1.00
21	Th	24	12.0	<0.1	<0.1	—	8.0	8.4	8.1	—	—	—	—	—	—	<0.1	—
28	Th	24	12.0	<0.1	<0.1	—	8.5	8.9	8.3	—	—	—	—	—	—	<0.1	—
Total			49.5	<0.1	0.1		32.9	25.9	32.6				0.04			<0.1	1.77
Avg.			12.4	<0.1	<0.1		8.2	8.6	8.2				0.04			<0.1	0.89
Max			12.5	<0.1	<0.1		8.6	8.9	8.3				0.04			<0.1	1.00
Min			12.0	<0.1	<0.1		7.8	8.4	8.0				0.04			<0.1	0.77

MONTH YEAR DATE	Flow Rate M.G.	Time of Sampling	Station E-1			Station EP-1	Station [illegible]-2		
			D.O. mg/L	Dis. H2S mg/L	pH	D.O. mg/L	D.O. mg/L	Dis. H2S mg/L	Set. Sol. ml/L
1	1.4	1630	.3	<0.1	7.9	9.6	25.0	<0.1	<0.1
2	1.3	1630	.4	<0.1	8.1	10.2	23.4	<0.1	<0.1
3	1.3	1630	.4	<0.1	8.2	9.0	27.6	<0.1	<0.1
4	1.5	17:00	.6	<0.1	8.0	7.8	27.2	<0.1	<0.1
5	2.0	17:00	.4	<0.1	8.5	7.9	28.0	<0.1	<0.1
6	1.3	16:30	.3	<0.1	8.3	8.5	27.6	<0.1	<0.1
7	1.6	16:00	.4	<0.1	8.2	8.8	24.2	<0.1	<0.1
8	1.1	16:00	.8	<0.1	7.8	8.6	16.0	<0.1	<0.1
9	1.8	16:30	.4	<0.1	8.0	9.2	24.6	<0.1	<0.1
10	1.5	16:30	.3	<0.1	8.4	9.0	25.2	<0.1	<0.1
11	1.4	1630	.3	<0.1	7.9	7.8	24.2	<0.1	<0.1
12	0.3	1700	.3	<0.1	7.8	8.6	21.6	<0.1	<0.1
13	1.4	1700	.5	<0.1	7.9	8.2	22.4	<0.1	<0.1
14	0.5	1700	.6	<0.1	8.0	8.[illegible]	18.0	<0.1	<0.1
15	.4	1700	.4	<0.1	7.7	8.0	9.4	<0.1	<0.1
16	0.9	1700	0.4	<0.1	8.0	7.0	4.8	[illegible]	<0.1
17	0.7	1700	0.6	<0.1	7.9	7.2	8.8	<0.1	<0.1
18	[illegible]	1700	.5	<0.1	7.8	8.1	[illegible]	[illegible]	<0.1
19	[illegible]	1700	.3	[illegible]	7.9	[illegible]	[illegible]		[illegible]
20	.8	1730	.6	<0.1	7.8	9.7	15.6	<0.1	<0.1
21	1.1	1730	.4	<0.1	8.0	8.1	9.1	<0.1	<0.1
22	.7	1730	.8	<0.1	7.8	8.4	12.2	<0.1	<0.1
23	.9	1730	.6	<0.1	7.9	7.9	13.1	<0.1	<0.1
24	.8	1730	.7	<0.1	7.8	7.5	9.0	<0.1	<0.1
25	1.7	1730	.3	<0.1	7.5	[illegible]	17.0	<0.1	<0.1
26	1.8	1730	.3	<0.1	7.4	8.8	16.0	<0.1	<0.1
27	1.8	1730	.3	<0.1	7.5	9.0	25.0	<0.1	<0.1
28	1.6	1730	.7	<0.1	[illegible]	7.5	25.5	<0.1	<0.1
29	1.6	1730	1.0	<0.1	8.3	8.7	[illegible]	[illegible]	<0.1
30	1.6	1730	.7	<0.1	7.9	7.0	16.2	<0.1	<0.1
~~31~~									
Total	37.4		14.8	<0.1	[illegible]	252.2	570	<0.1	<0.1
Max.	2.0		1.0	<0.1	8.5	10.2	28.0	<0.1	<0.1
Min.	0.3		0.3	<0.1	7.4	7.0	4.8	<0.1	<0.1
Avg.	1.25		0.5	<0.1	7.9	8.4	19.0	<0.1	<0.1

PLEASANTON [illegible]

Month of [illegible] 1977

Monthly Analytical Data Sheet No. 4

Activated Sludge

DATE	DAY	PLANT FLOW M.G.D.	BIO-AERATORS BLOWERS			MIXED LIQUOR BIO-SUMP No. II				BIO-AERATION TANK		R.A.S.				
			No. 146 HOURS ON	No. 147 HOURS ON	Million C.F.D.	AVG PH	AVG SUS. SOL.	AVG. SET. SOL.	AVG S.V.I.	AVG SUS. SOL.	AVG. D.O.	AVG. PH	WASTE R.A.S. [illegible]	R.A.S. M.G.D.	% RETURN	% Ash
F	1	1.154	24	12	0.680	7.8	3720	240	65	9480		7.6	21600	1.18	102	
Sa	2	1.178	12	24	"	8.1	3520	250	70	9520		7.9	"	"	100	
Su	3	1.091	24	12	"	8.2	3540	270	76	9870		7.8	"	"	108	
M	4	1.179	12	24	"	7.9	3480	250	72	9840		7.6	"	"	100	
Tu	5	1.091	24	12	"	7.7	4140	270	65	9970		7.5	"	"	108	
W	6	1.068	12	24	"	8.1	3770	280	74	8890		7.6	"	"	110	
Th	7	1.140	24	12	"	8.2	3220	240	75	8680		7.7	"	"	103	
F	8	1.103	12	24	"	7.8	2880	220	76	7740		7.5	"	"	107	
Sa	9	1.160	24	12	"	7.6	2990	260	88	8420		7.4	"	"	102	
Su	10	1.114	12	24	"	8.1	2540	190	75	7580		7.7	"	"	106	
M	11	1.148	24	12	"	8.1	2990	180	60	8270		7.7	"	"	103	
Tu	12	1.110	12	24	"	7.7	3350	165	51	8280		7.4	"	"	107	
W	13	1.098	24	12	"	7.9	3170	185	58	7290		7.4	"	"	108	
Th	14	1.197	12	24	"	7.8	3160	190	60	7800		7.6	"	"	99	
F	15	1.118	24	12	"	7.7	2740	170	62	8340		7.6	"	"	105	
Sa	16	1.134	12	24	"	7.8	2600	135	52	6530		—	"	"	104	
Su	17	1.138	24	12	"	7.9	2290	120	52	7620		7.6	"	"	104	
M	18	1.159	12	24	"	7.8	2308	140	61	6240		7.5	"	"	102	
Tu	19	1.128	24	12	"	7.8	2512	150	60	6020		7.6	"	"	104	
W	20	1.100	12	24	"	7.8	2088	110	53	5280		7.6	"	"	107	
Th	21	1.113	24	12	"	7.7	1784	110	62	4950		7.6	"	"	106	
F	22	1.214	12	24	"	7.8	1948	100	57	4900		7.6	"	"	97	
Sa	23	1.117	24	12	"	7.7	1888	100	53	5290		7.6	"	"	105	
Su	24	1.114	12	24	"	7.8	1872	105	56	5160		7.6	"	"	106	
M	25	1.158	24	12	"	7.4	1516	120	79	5388		7.5	"	"	102	
Tu	26	1.099	12	24	"	7.8	3260	130	40	5988		7.3	"	"	108	
W	27	1.104	24	12	"	7.5	3072	150	49	7316		7.4	"	"	106	
Th	28	1.096	12	24	"	7.4	3432	200	58	6152		7.6	"	"	108	
F	29	1.223	24	12	"	8.5	1960	190	97	6220		7.4	"	"	96	
Sa	30	1.112	12	24	"	7.8	3250	180	55	8160		7.5	"	"	106	
TOTAL		33.958	540	540	21.08	235.4	84730	5400	1911	220824		219.4	648000	35.4	3129	
AVG.		1.132	18	18	0.680	7.9	2824	180	64	7363		7.6	21600	1.18	104	
MAX.		1.223	24	24	0.680	8.5	4140	280	97	9970		7.9	21600	1.18	108	
MIN.		1.091	12	12	0.680	7.4	1516	100	40	4900		7.3	21600	1.18	96	

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of *April* 1977

PLANT OPERATING DATA

DATE	DAY	SLUDGE, GALLONS					TEMP. °F		SLUDGE CIRC., hrs.		GAS PRODUCED 1000 CU FT		UTILITIES				
		SCUM SUMP PUMP	RAW SLUDGE PUMP	prim. DIG TO BEDS	sec. DIG TO beds		DIG NO. 1	DIG NO. 2	DIG NO. 1	DIG NO. 2	DIG NO. 1	DIG NO. 2	ELECT POWER KW HRS	NAT. GAS 1000 CU FT			
1		1106	18087										2320	97			
2		1260	18096						2				2320	97			
3		1060	18165										2320	96			
4		1273	18452		18000				2				2320	92			
5		1113	18382	3000	9000								2240	92			
6		1900	17339						2				2320	91			
7		1120	18095										2240	98			
8		1240	18104						2				2320	80			
9		1340	18086										2240	91			
10		1331	18096						2				2320	93			
11		1047	18835		24000								2240	92			
12		1247	18096	6000	18000				2				2240	91			
13		1047	18096										2320	91			
14		833	18209						2				2240	93			
15		1053	18061										2240	91			
16		1160	18374						2				2240	89			
17		1160	18200										2240	89			
18		1287	17965		15000				2				2240	87			
19		1137	18287										2240	85			
20		1407	18235						2				2240	88			
21		1400	18722										2240	74			
22		1207	18252						2				2160	78			
23		1007	17443										2240	78			
24		1130	18322						2				2160	75			
25		1331	18096										2240	80			
26		1127	18209						2				2240	82			
27		1267	17965										2240	83			
28		1234	18296						2				2160	83			
29		1331	18844										2240	79			
30		1331	18096						2				2320	81			
31																	
TOTAL		37026	545765	9000	84000				30				67680	2616			
AVERAGE		1234	18190						2				2256	87			
MAXIMUM		1900	18844						2				2320	97			
MINIMUM		833	17339						2				2160	75			

PLEASANTON WATER POLLUTION CONTROL PLANT

Month of April 1977

ANALYTICAL DATA No. 5.

Sludge Digestion

DATE	DAY	Total Solids % Raw Sludge	Total Solids % Prim Bot.	Total Solids % Prim Super	Total Solids % Sec Bot.	Total Solids % Sec. Super	Vol. Solids % Raw Sludge	Vol. Solids % Prim Bot.	Vol. Solids % Prim Super	Vol. Solids % Sec. Bot.	Vol. Solids % Sec. Super	pH Prim.	pH Sec.	Vol. Acids mg/L Prim	Vol. Acids mg/L Sec.	Alkalinity mg/L Prim.	Alkalinity mg/L Sec.
4	M			1.2		0.7											
5	Tu		7.4		6.4												
11	M			1.3		0.6						7.5	7.6	155	100	2640	3030
12	Tu		7.2		6.8												
Total			14.6	2.5	13.2	1.3											
Avg.			7.3	1.3	6.6	0.7											
Max.			7.4	1.3	6.8	0.7											
Min.			7.2	1.2	6.4	0.6											

Vol. Red. Prim = — Sec. = —

WEEKLY H2S RESULTS IN AIR. Sheet No. 6

Station No.	PLANT PERIMETER Tag on Date & Time	Tag off Date & Time	Elapsed Time Days	Color Grade	H_2S ug/L	Station No.	SLUDGE DRYING BEDS Tag on Date & Time	Tag off Date & Time	Elapsed Time Days	Color Grade	H_2S ug/L
1	3/28 [illegible]	[illegible]	7	0.25	[illegible]	L-2	3/28 [illegible]	[illegible]	7	<0.25	[illegible]
2	"		"	0.25	[illegible]	L-4	"		"	"	"
3	"		"	0.25	[illegible]	L-6	"		"	"	"
4	"		"	<0.25	[illegible]	L-8	"	"	"	"	"
1	4/4 @0800	4/11 @0800	7	0.25	0.00020	L-2	4/4 @0800	4/11 @0800	7	<0.25	<0.00020
2	"	"	"	0.25	0.00020	L-4	"	"	"	"	"
3	"	"	"	<0.25	<0.00020	L-6	"	"	"	"	"
4	"	"	"	<0.25	<0.00020	L-8	"	"	"	"	"
1	4/11 @0800	4/18 @0800	7	<0.25	<0.00020	L-2	4/11 @0800	4/18 @0800	7	<0.25	<0.00020
2	"	"		"	"	L-4	"	"	"	"	"
3	"	"	"	"	"	L-6	"		"	"	"
4	"	"		"	"	L-8	"		"	"	"
1	[illegible]	[illegible]	[illegible]	<0.25	<0.00020	L-2	[illegible]	[illegible]	"	<0.25	<0.00020
2	"	"	"	0.25	0.00020	L-4	"	"	"	"	"
3	"		"	<0.25	<0.00020	L-6	"		"	"	"
4	"	"		<0.25	<0.00020	L-8	"	"	"	"	"
1	4/25 @0800	5/2 @0800	7	<0.25	<0.00020	L-2	4/25 @0800	5/2 @0800	7	<0.25	<0.00020
2	"	"	"	"	"	L-4	"	"	"	"	"
3	"	"	"	"	"	L-6	"	"	"	"	"
4	"	"	"	"	"	L-8	"	"	"	"	"
Total											
Avg.											
High											
Low											

Month **April** 1977

Additional Comments:

Average percentage reductions for the month:

	Primary Effl.	Sec. Clar. Effl.
B.O.D.	59%	92%
Sus. Sol.	74%	92%

Industrial discharge monitoring

Pleasanton Cheese Factory Monthly Averages Used For Fee Calculations

Flow (gpd)	6,582
B.O.D. (mg/L)	2,640
Sus. Sol. (mg/L)	683
pH (Units)	5.6

APPENDIX B
PRE-FAIR OPERATIONAL PROCEDURE CHANGES AT CITY OF PLEASANTON SEWAGE TREATMENT PLANT

ENTRY NUMBER	DATE	OPERATIONAL CHANGES	FLOW PATTERN CHANGES	POSSIBLE ANALYSIS AFFECTED
10.	5-31-76	Added 750 lbs. of digestor solids to bio-aerator.	None	0-24 hr. increase in B.O.D 24+ hrs. decrease in B.O.D
11.	6- 2-76	Wasted 4800 lbs. R.A.S. to primary sedimentary tanks.	None	Lower suspended solids.
12.	6- 3-76	Wasted 2400 lbs R.A.S. to primary sedimentary tanks.	None	Lower suspended solids.
13.	6- 7-76	Started waste R.A.S. constant waste @14000 g.p.d. to primary sedimentary tanks.	None	Lower suspended solids, possible stabilization of plant operation.
14.	6- 8-76	Added 750 lbs. of digestor solids to bio-aerator.	None	0-24 hr. increase in B.O.D 24+ hrs. decrease in B.O.D
15.	6-10-76	Added 1500 lbs. of digestor solids to bio-aerator.	None	0-24 hr. increase in B.O.D 24+ hrs. decrease in B.O.D
16.	6-14-76	Recirculating pipe removed temporarily so that truck traffic might pass. Will be replaced by 6-22 for dye retention study.	See Note 1	Unknown
17.	6-15-76	Added 1500 lbs. of digestor to bio-aerator.	None	0-24 hr. increase in B.O.D 24+ hrs. decrease in B.O.D

NOTE 1. No flow returning to pond 1 from pond 2.

Footnote: R.A.S. is Return Activated Sludge

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CITY OF PLEASANTON OPERATIONAL CHANGES

ENTRY NUMBER	DATE	OPERATIONAL CHANGES	FLOW PATTERN CHANGES	POSSIBLE ANALYSIS AFFECTED
1.	5-6-76	New filter pump operable in bio-sump #1.	Eliminated the primary bypass to oxidation ponds during daily peak flows.	Lower B.O.D. levels, lower suspended solids, lower general analysis.
2.	5-10-76	Added 975 lbs. of digestor solids to bio-aerator.	None	0-24 hr. increase in B.O.D. 24+ hrs. Decrease in B.O.D.
3.	5-12-76	Added 1,447 lbs of digestor solids to bio-aerator.	None	0-24 hr. increase in B.O.D. 24+ hrs. decrease in B.O.D.
4.	5-13-76	Added 2,250 lbs. of digestor solids to bio-aerator.	None	0-24 hr. increase in B.O.D. 24+ hrs. decrease in B.O.D.
5.	5-17-76	Wasted 4,800 lbs. of R.A.S. to primary sedimentary tanks.	None	Lower suspended solids.
6.	5-17-76	Two small aerators inoperative pond #2.	None	Possibility of lowering oxygen content pond #2
7.	5-28-76	Added 375 lbs. of digestor solids to bio-aerator.	None	0-24 hr. increase in B.O.D. 24+ hrs. decrease in B.O.D.
8.	5-29-76	Added 750 lbs. of digestor solids to bio-aerator.	None	0-24 hr. increase in B.O.D. 24+ hrs. decrease in B.O.D.
9.	5-29-76	Electrical malfunction which caused pumping pond 2 from level 2.6 to level 2.1. Pumping started 1030 5-28 - 0730 5-29.	None	Possible decrease ~~increase~~ in suspended solids.

CITY OF PLEASANTON WASTEWATER TREATMENT NOTES

1. Suspended solids on aeration tank are variable due to operators trying to find optimum operational levels. Variation in BOD levels would be expected during the period of April - May - June, 1976.

2. City plant is trying to achieve an average 90% BOD removal through secondary clarifier effluent. The plant is trying to maintain 10,000 suspended solids and applied mix liquor at 3,000 application to trickling filter.

APPENDIX C
SYNOPTIC WEATHER MAPS FOR POST-FAIR AEROSOL RUNS

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SYNOPTIC REGIME NO. 1

Dye Trials # 1, 2, 4-11

Microbiological Trials # 1-5

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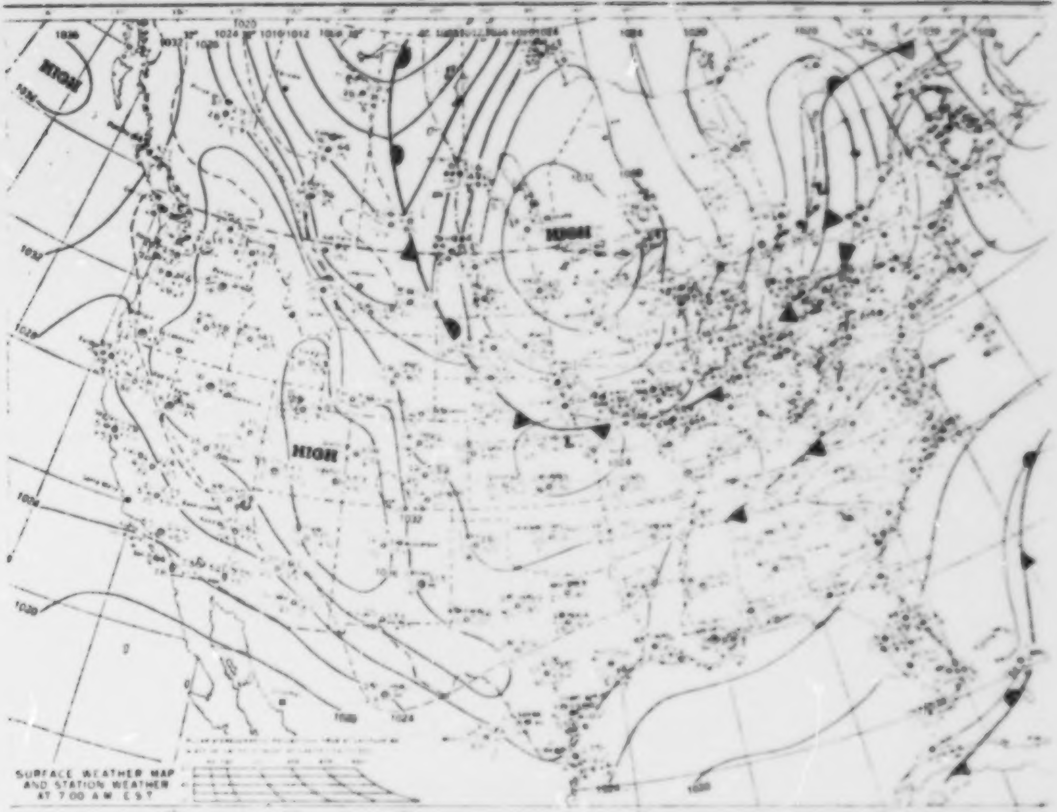
DECEMBER 2, 1976 Dye Trial # 1


HIGH
HIGH
HIGH
L
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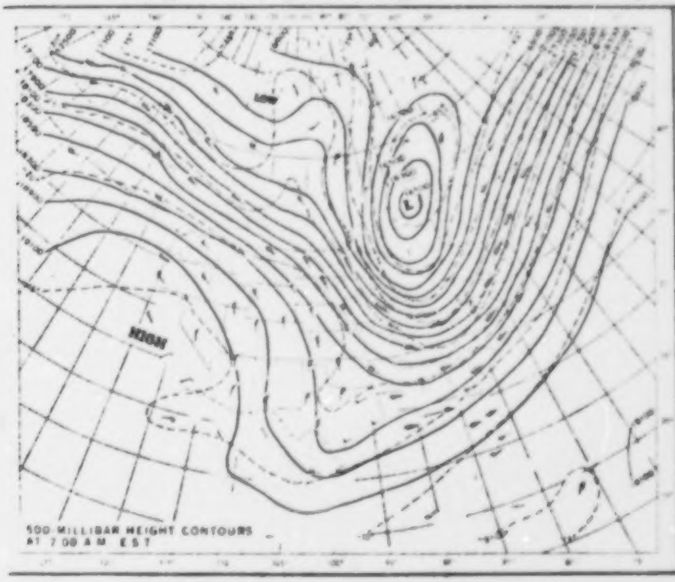
LOW
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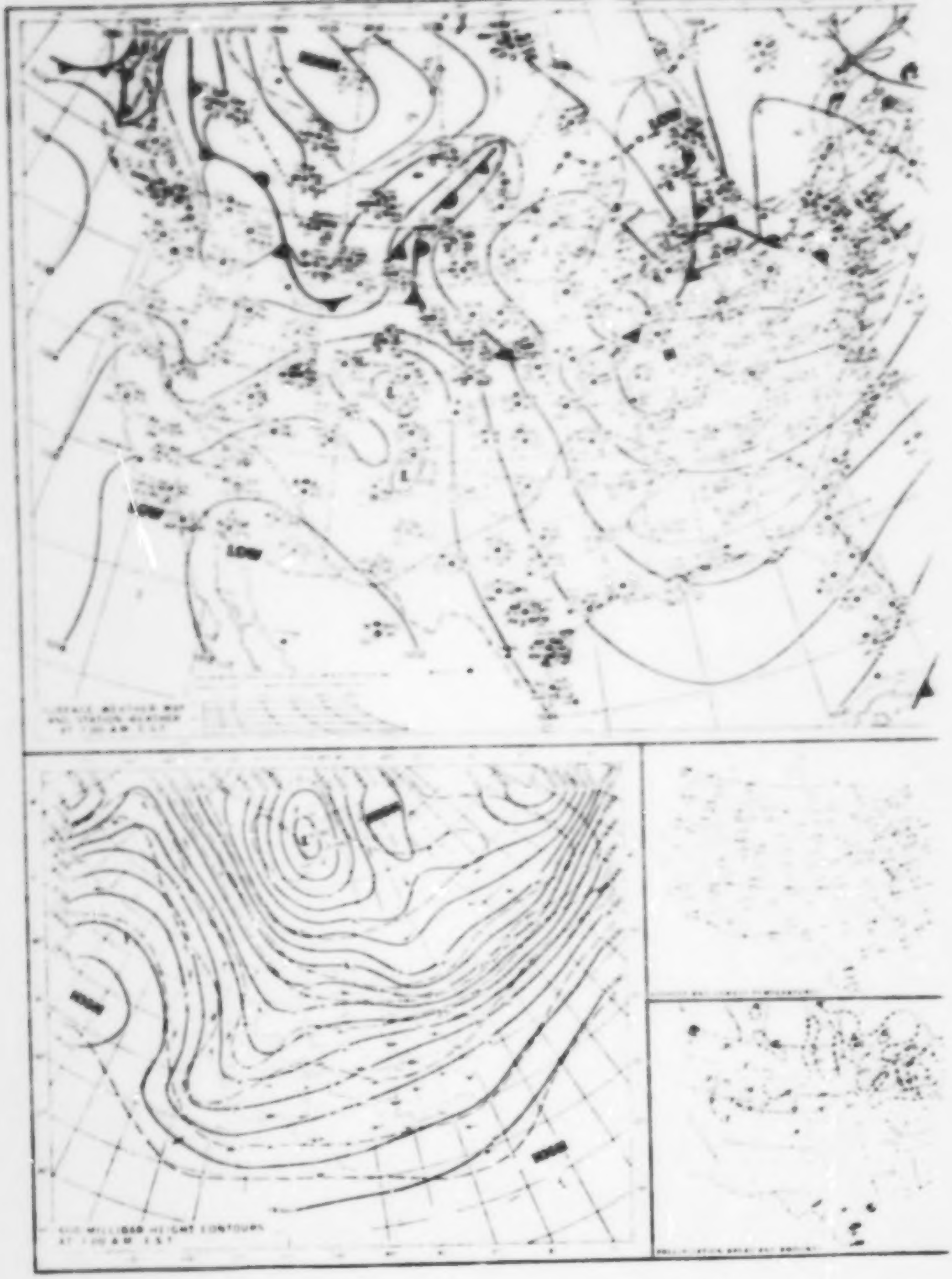
HIGH
500 MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.

HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

DECEMBER [illegible]   Dye Trial # 2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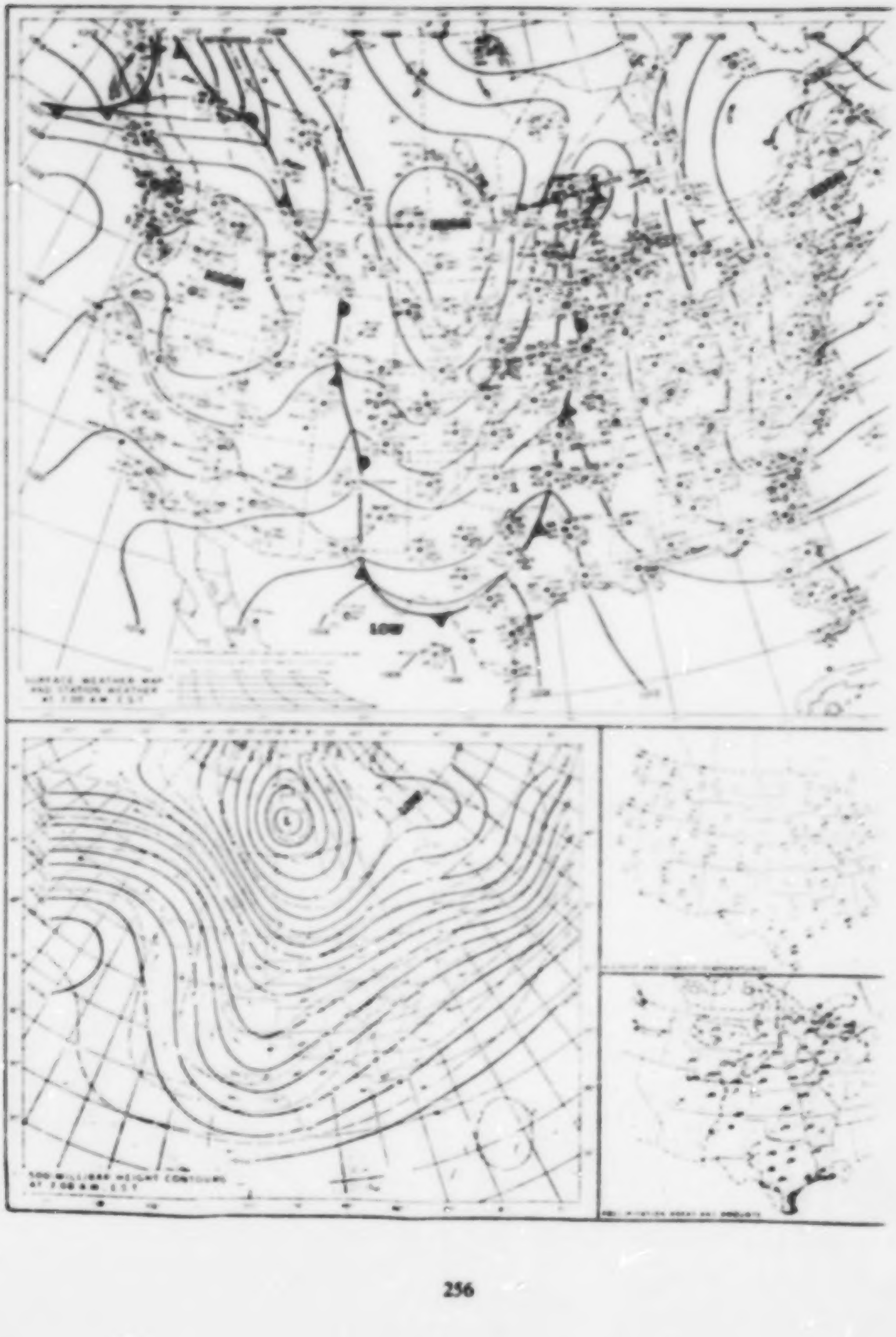
LOW
SURFACE WEATHER MAP AND STATION WEATHER AT 1:00 A.M. E.S.T.
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
PRECIPITATION AREAS AND AMOUNTS

DECEMBER 6, [illegible]   Dye Trial # 4, 5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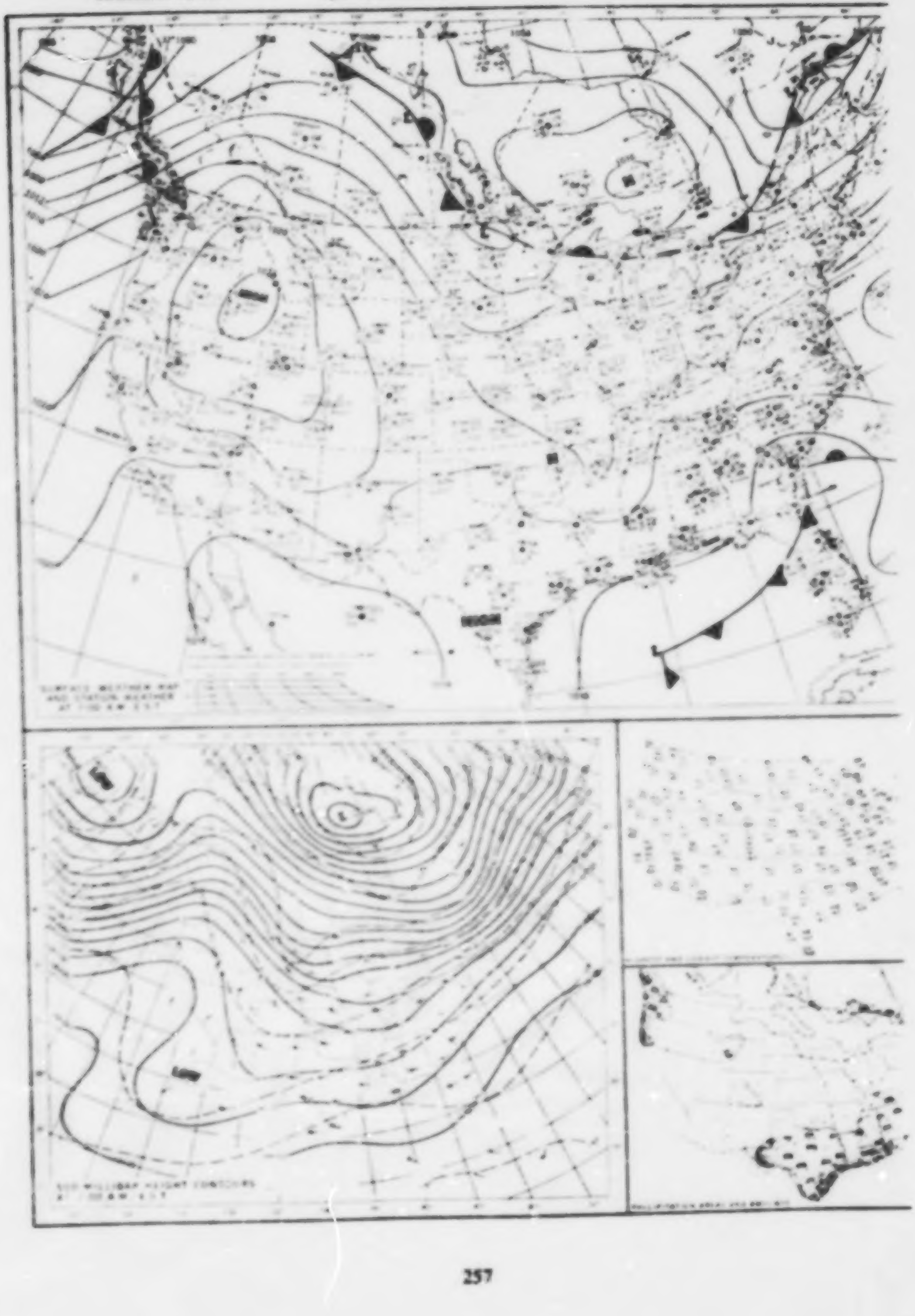
500-MILLIBAR HEIGHT CONTOURS

DECEMBER 15, 1976   Dye Trial # 6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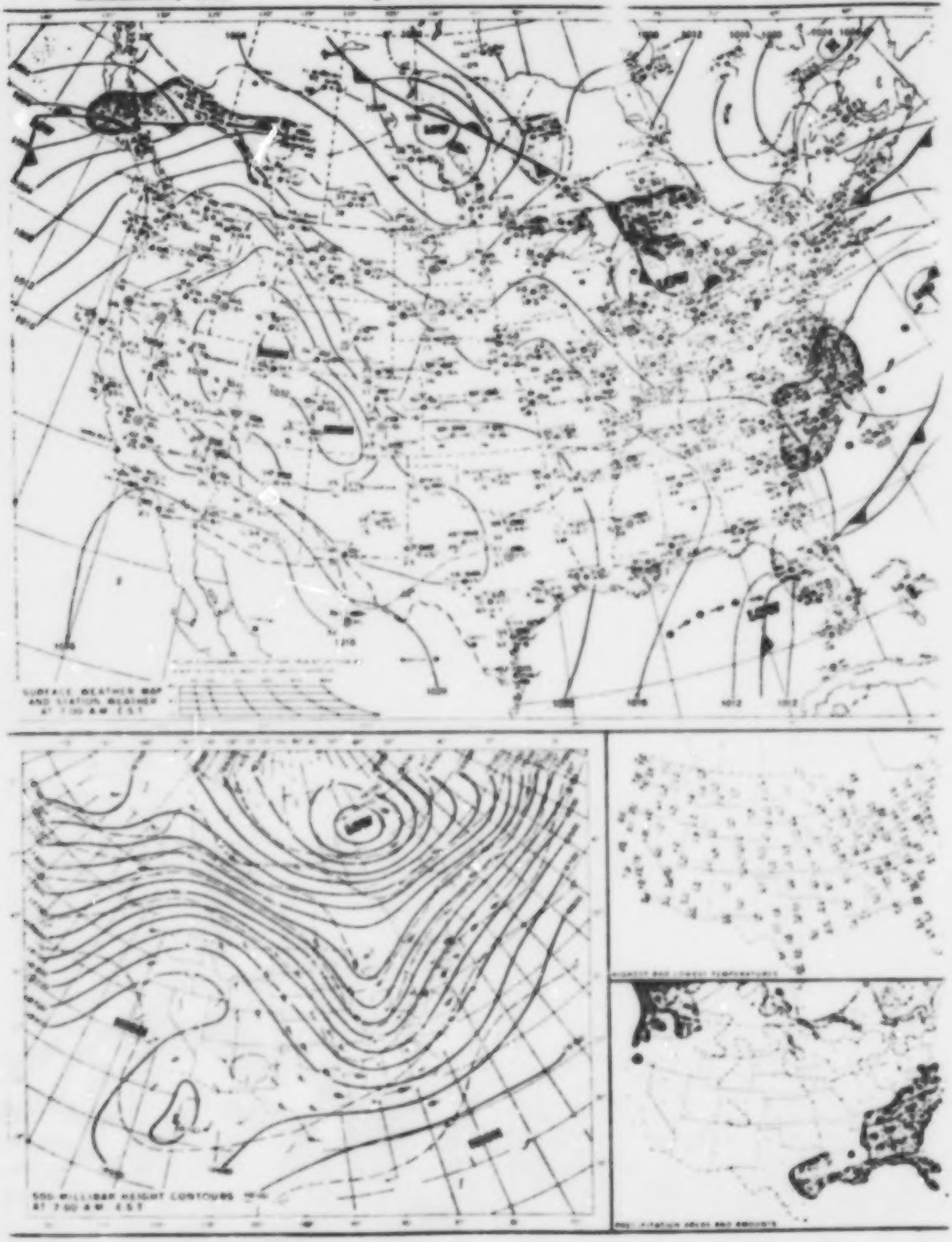
PRECIPITATION AREAS AND AMOUNTS

[redacted]16, 1976 Dye Trials # 7,8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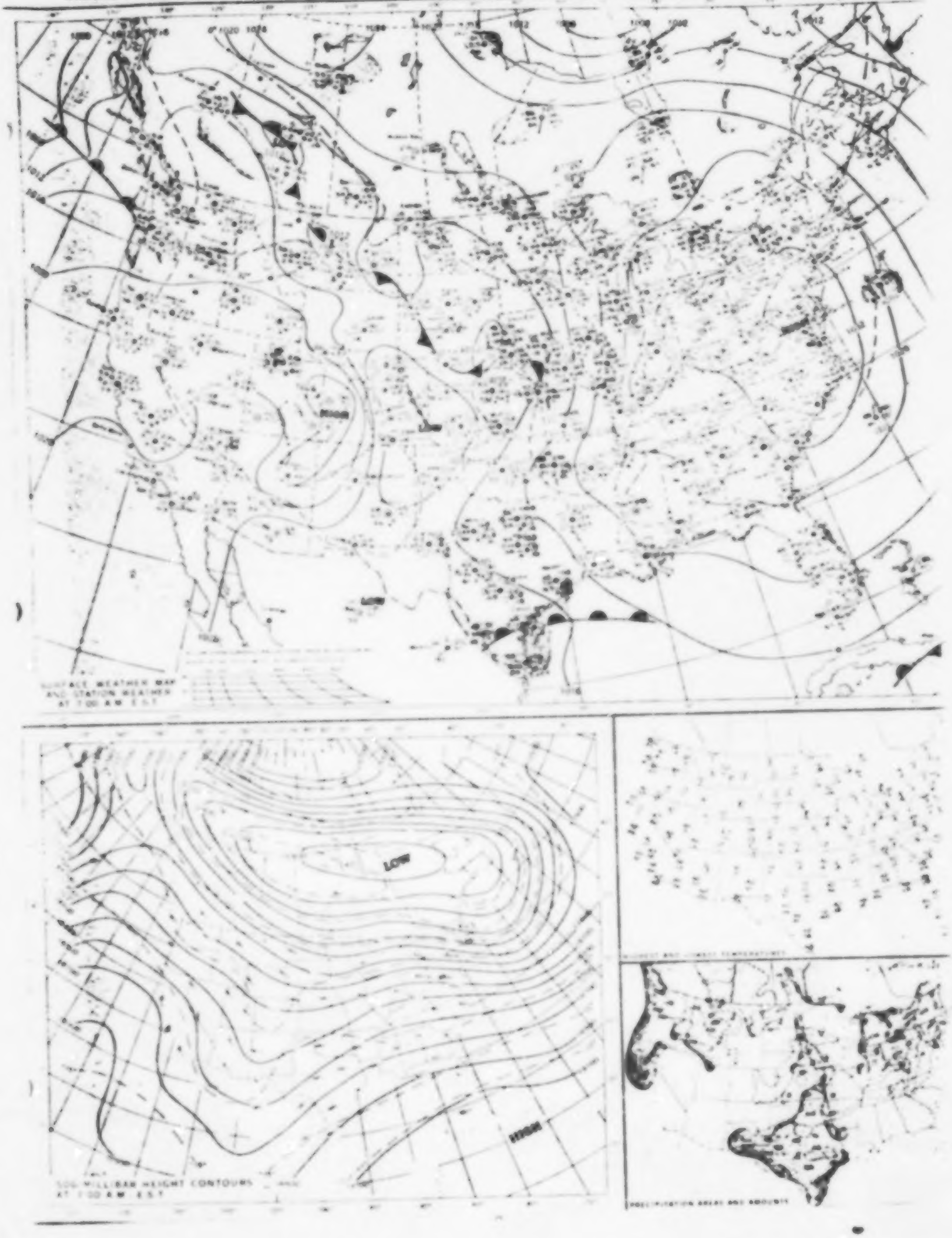
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

JANUARY 13, 1977 Dye Trials # 9-11


SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
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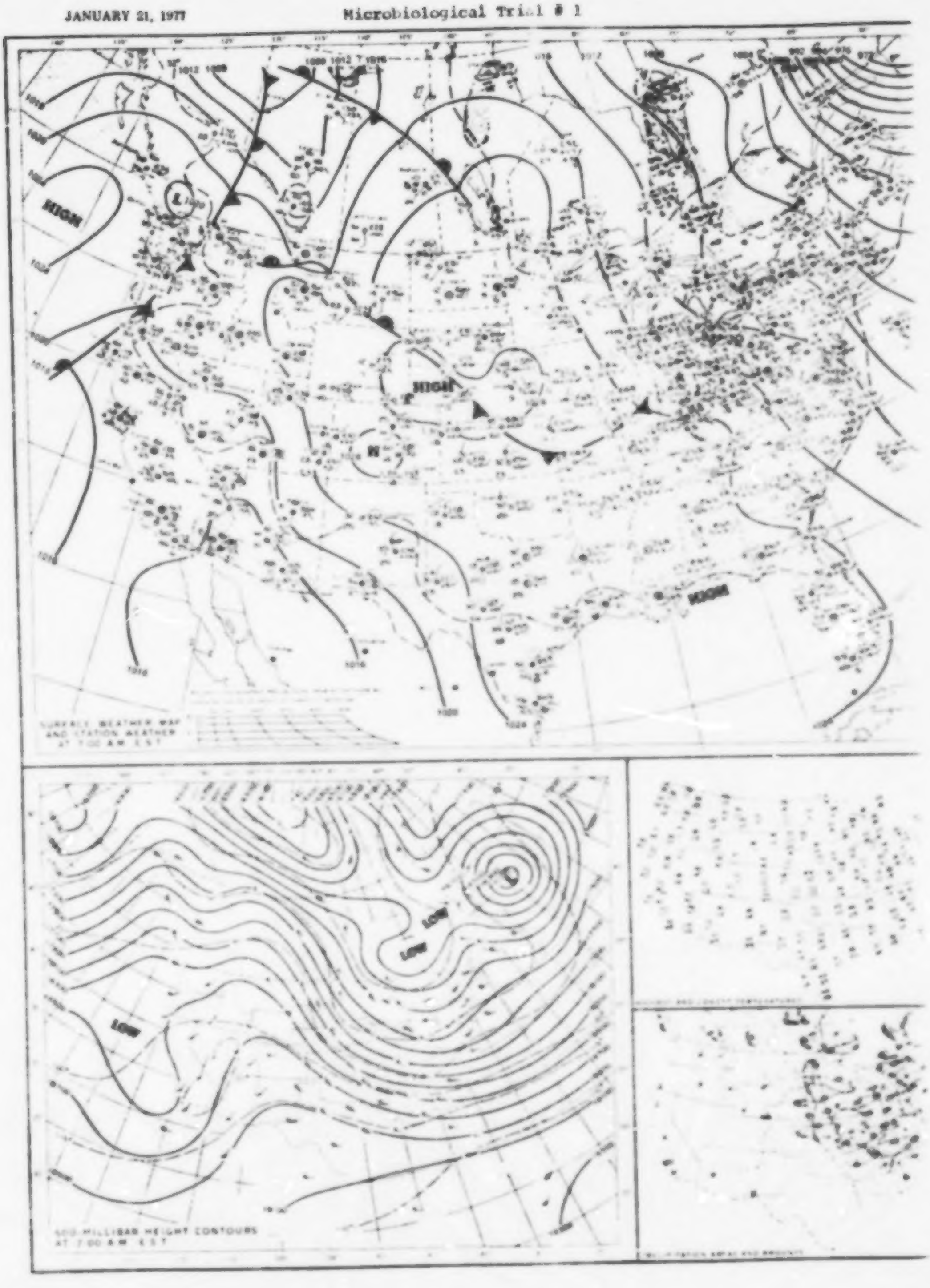
HIGH
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

JANUARY 21, 1977 Microbiological Trial # 1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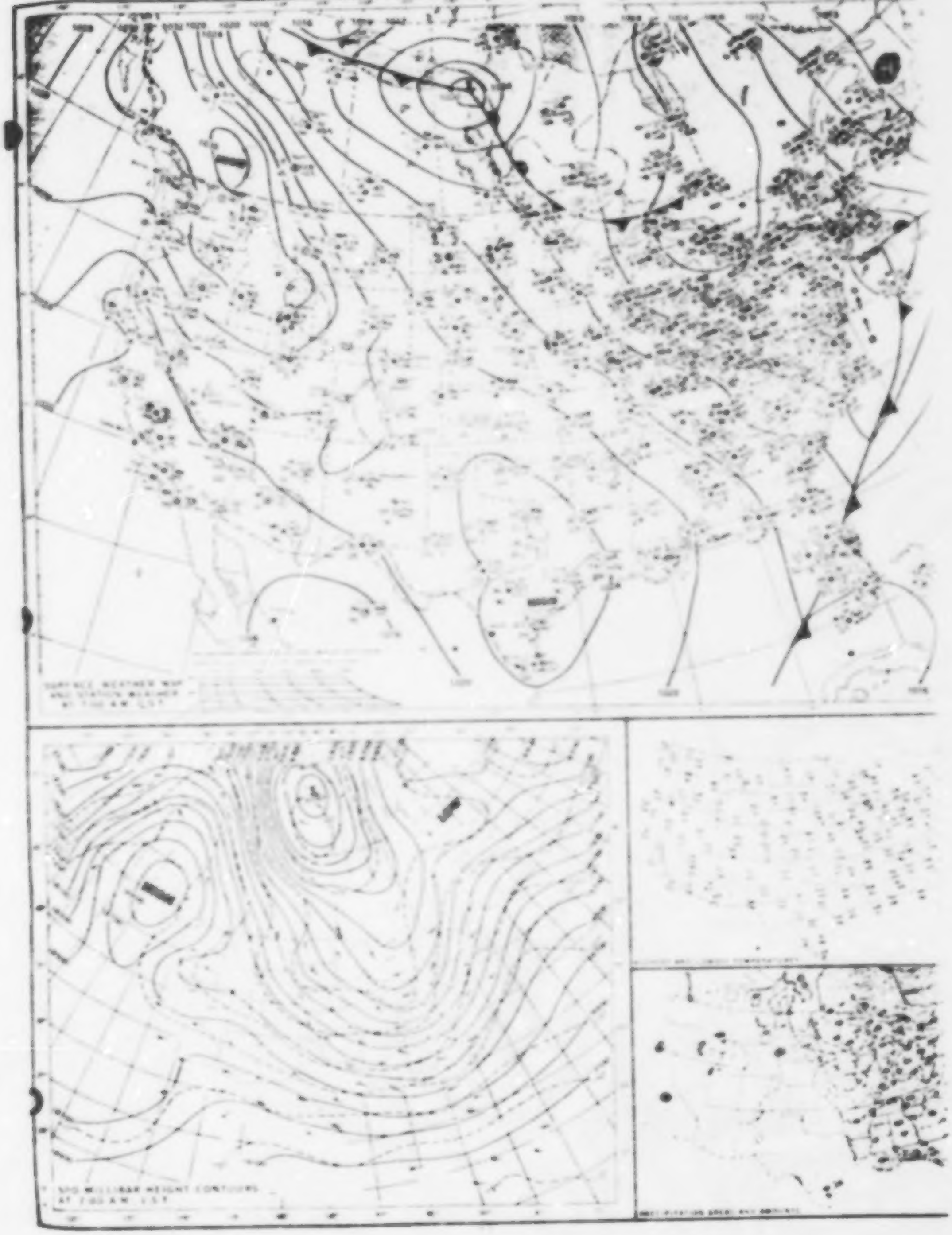
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.

JANUARY 25, 1977 Microbiological Trials # 3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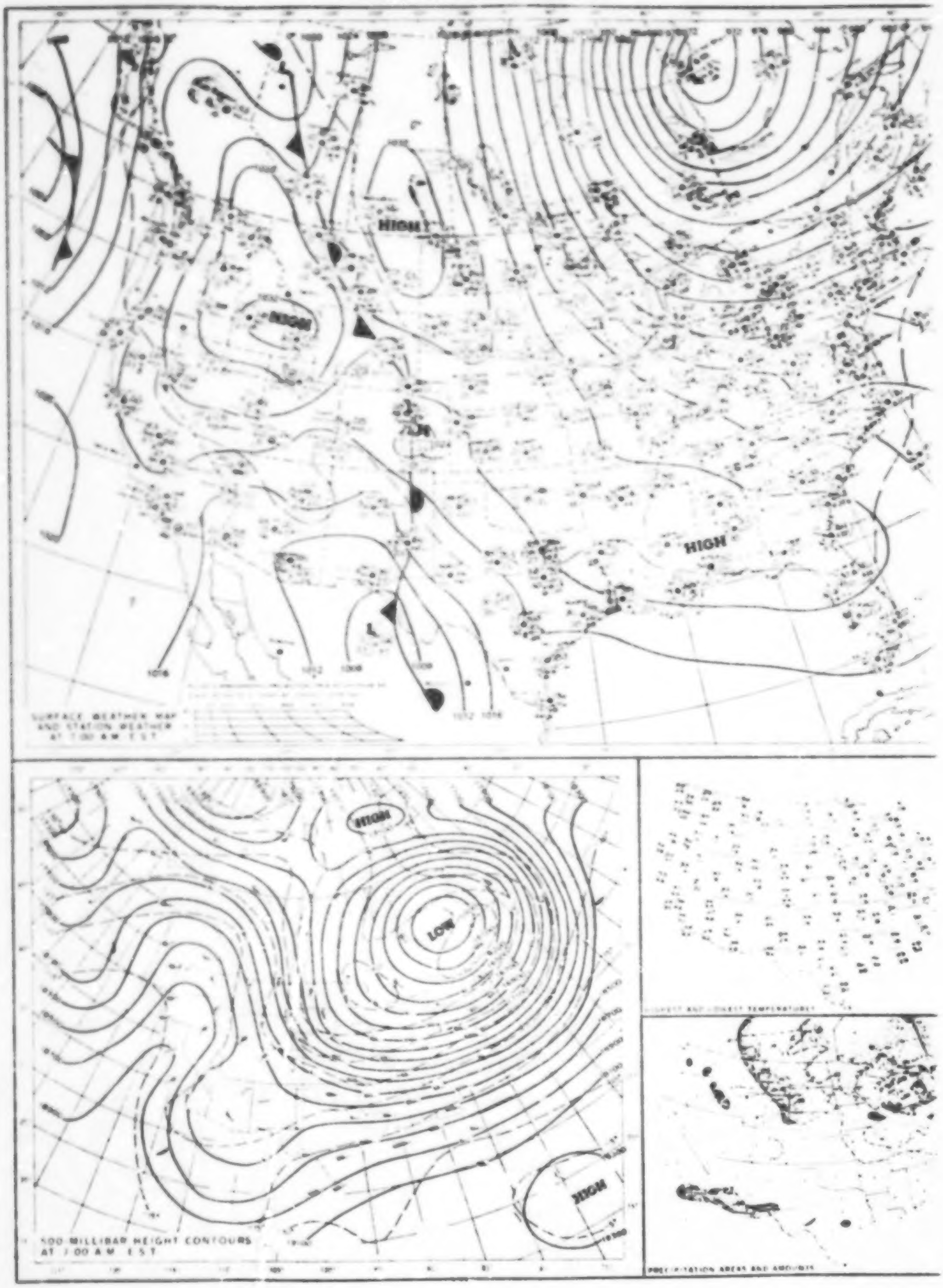
PRECIPITATION AREAS AND AMOUNTS

JANUARY 30, 1977 Microbiological Trials # 4, 5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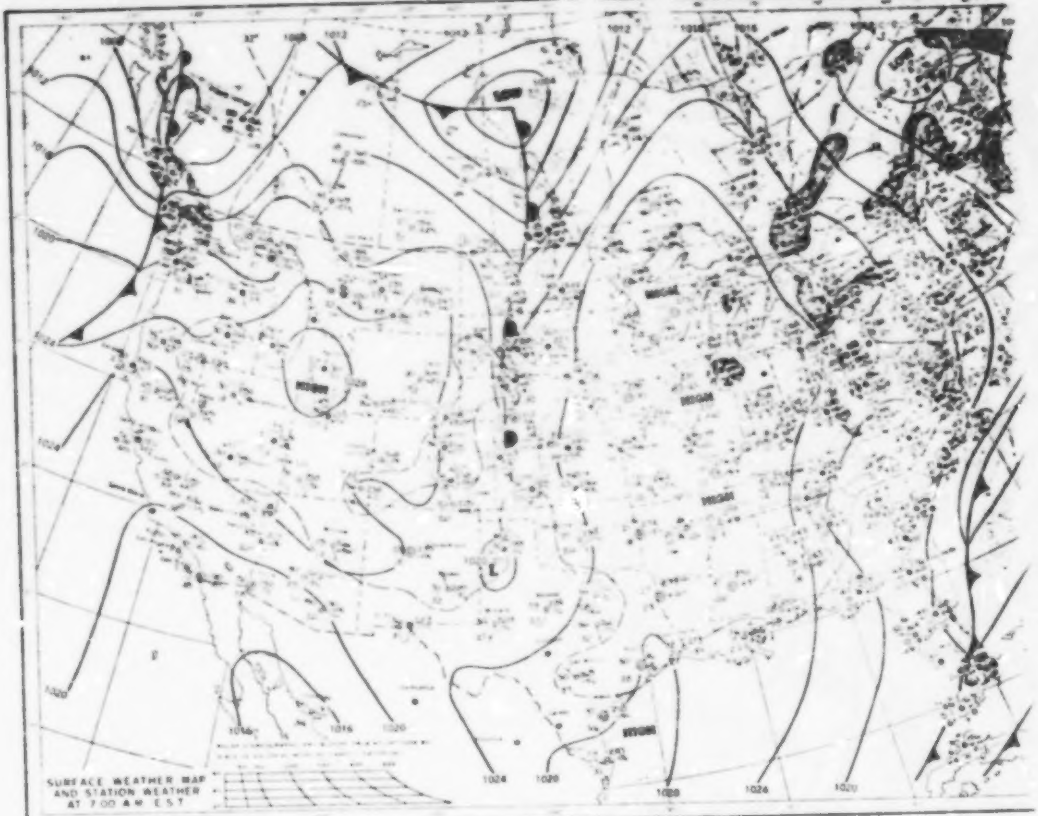
500 MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

SYNOPTIC REGIME NO. 2

Microbiological Trials # 8-10, 18-21, 31, 35, 36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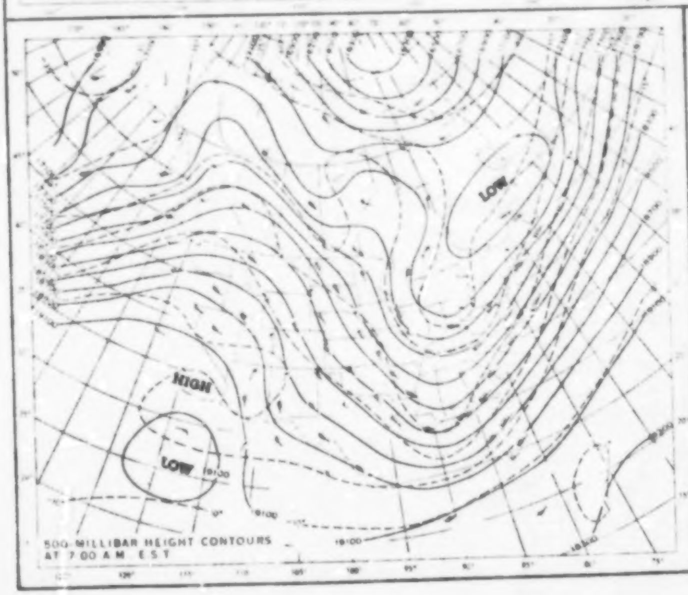
SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.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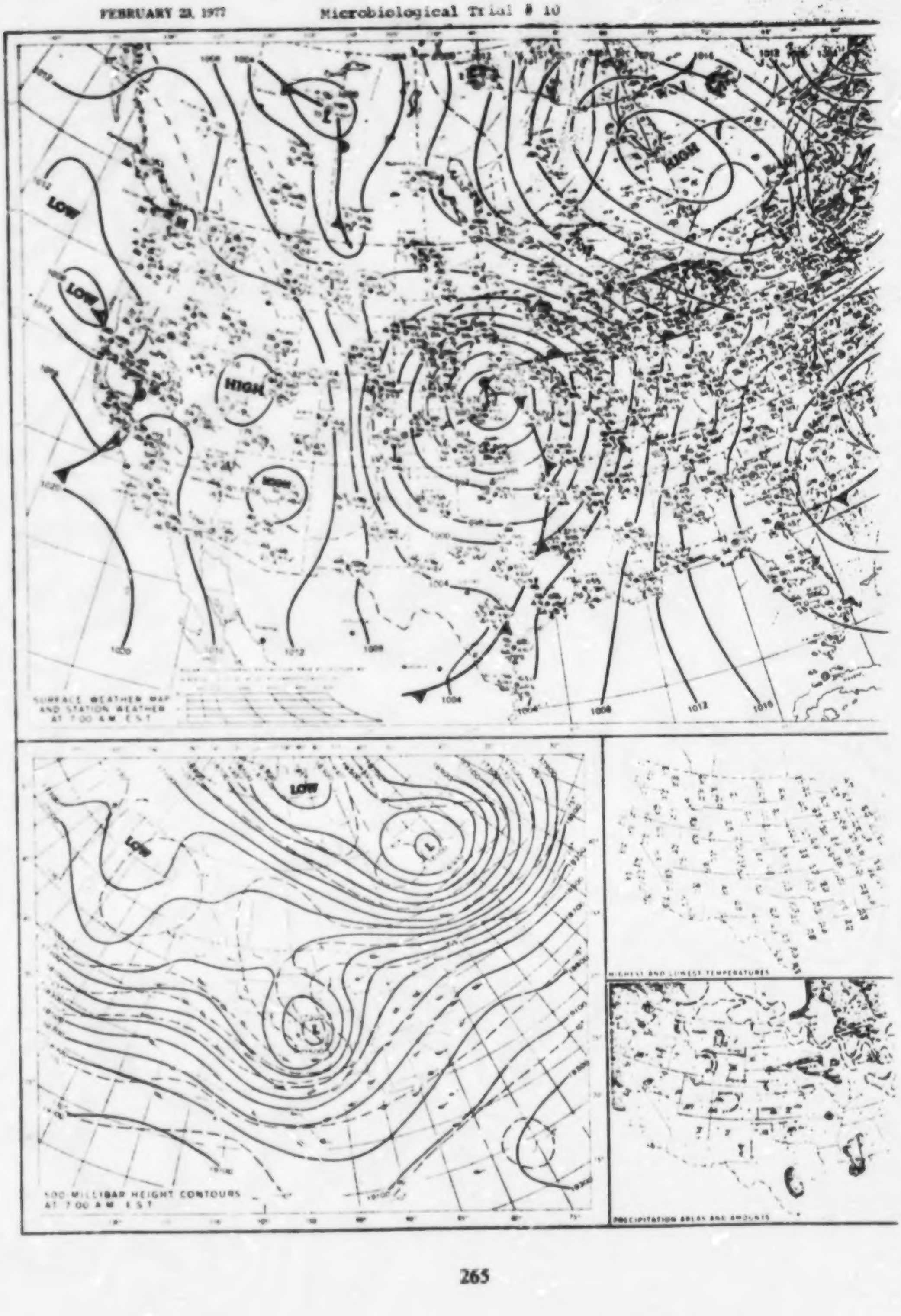
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.

HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

FEBRUARY 28, 1977 Microbiological Trial # 10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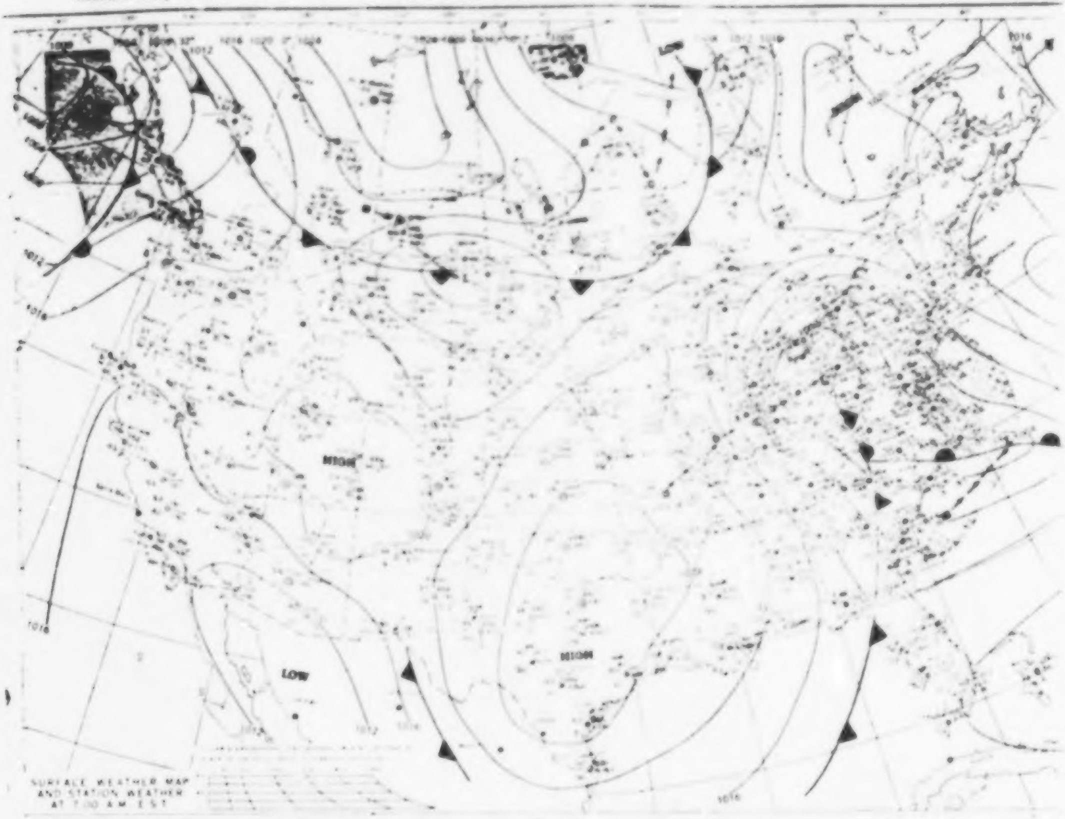
LOW
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

MARCH 22, 1977

(Microbiological)
Quality Assurance Trials # 8-21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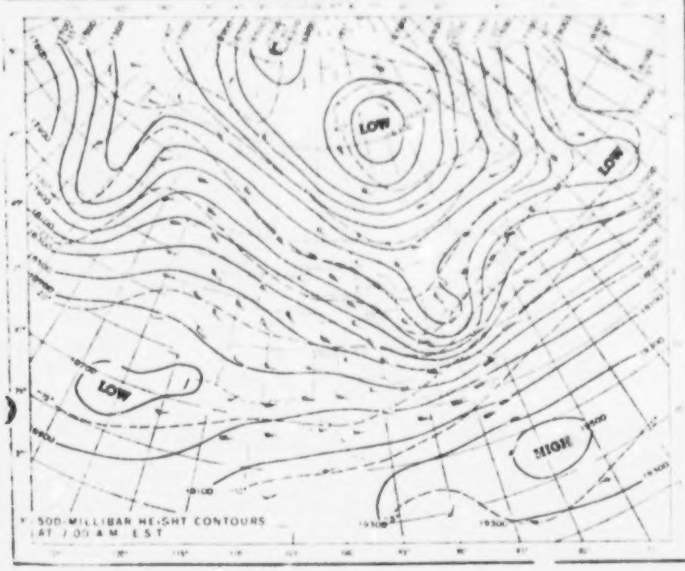
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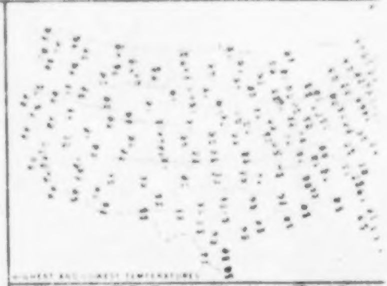

HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

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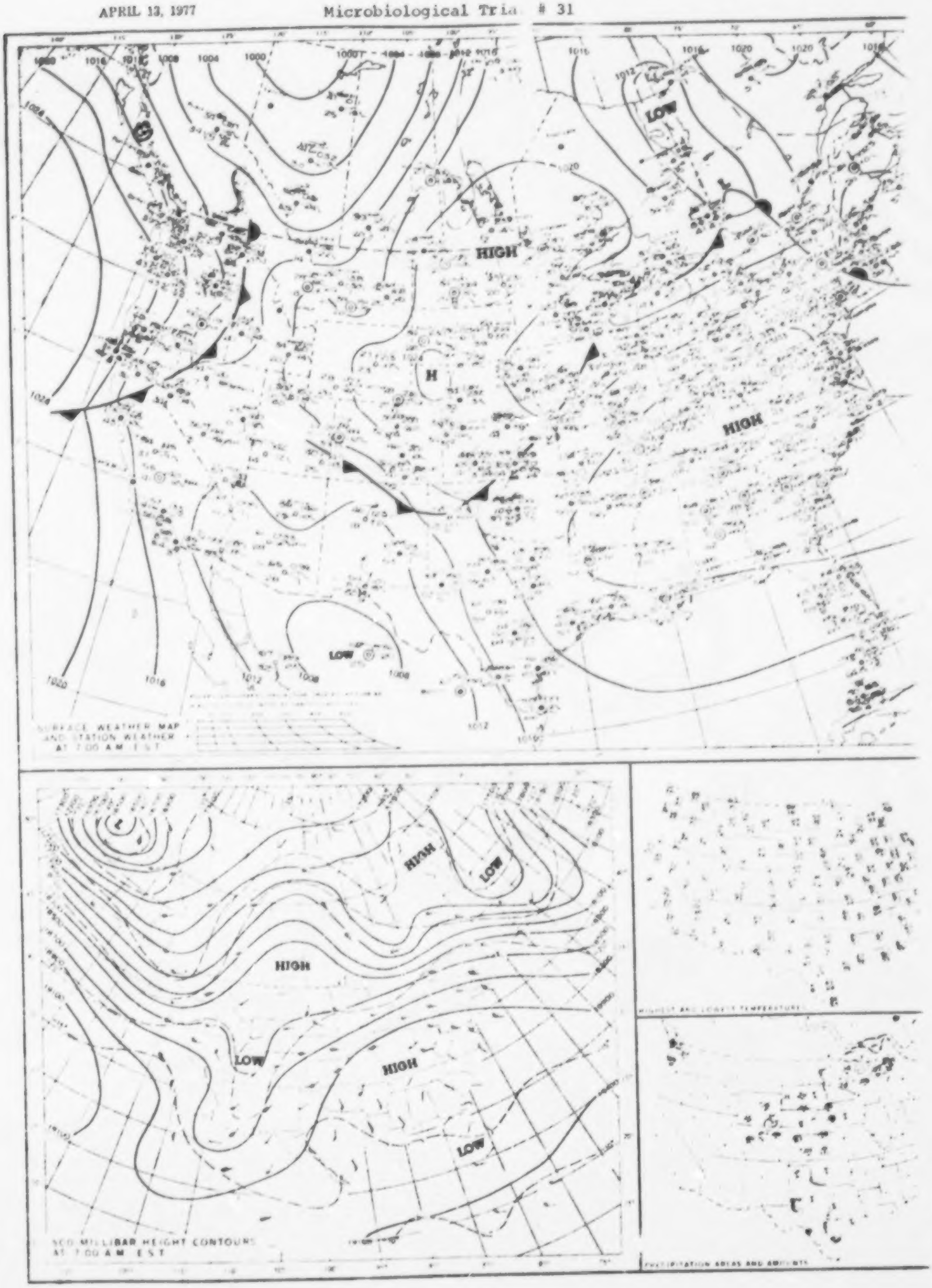
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SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
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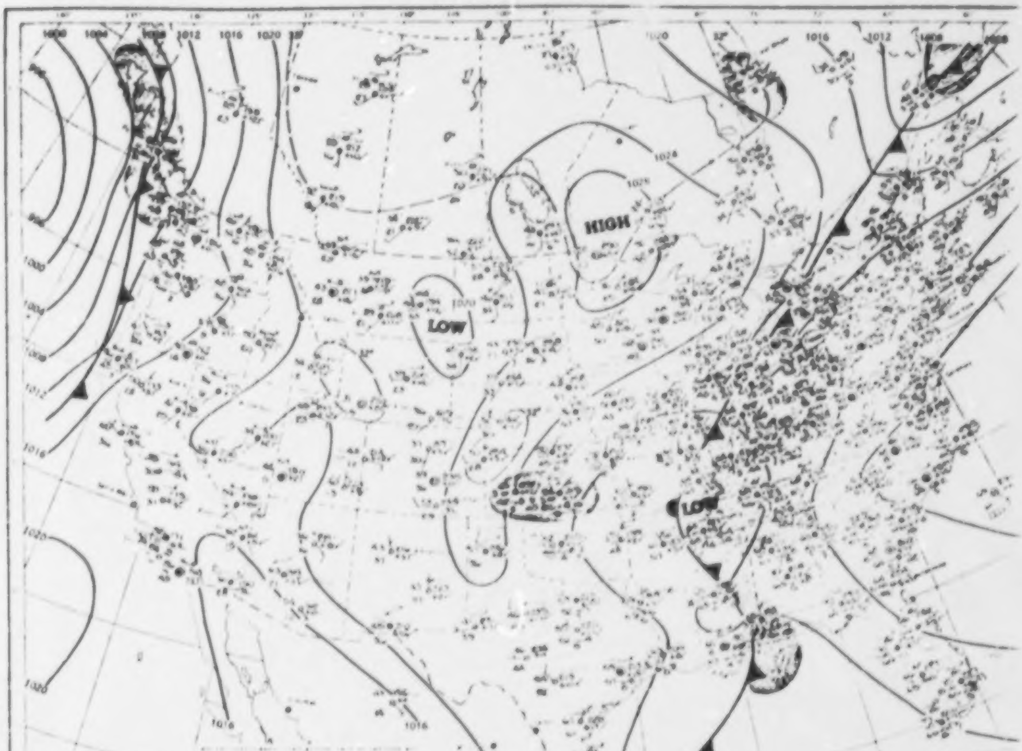
500 MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURE
PRECIPITATION AREAS AND AMOUNTS

APRIL 22, 1977 Microbiological Trial # 25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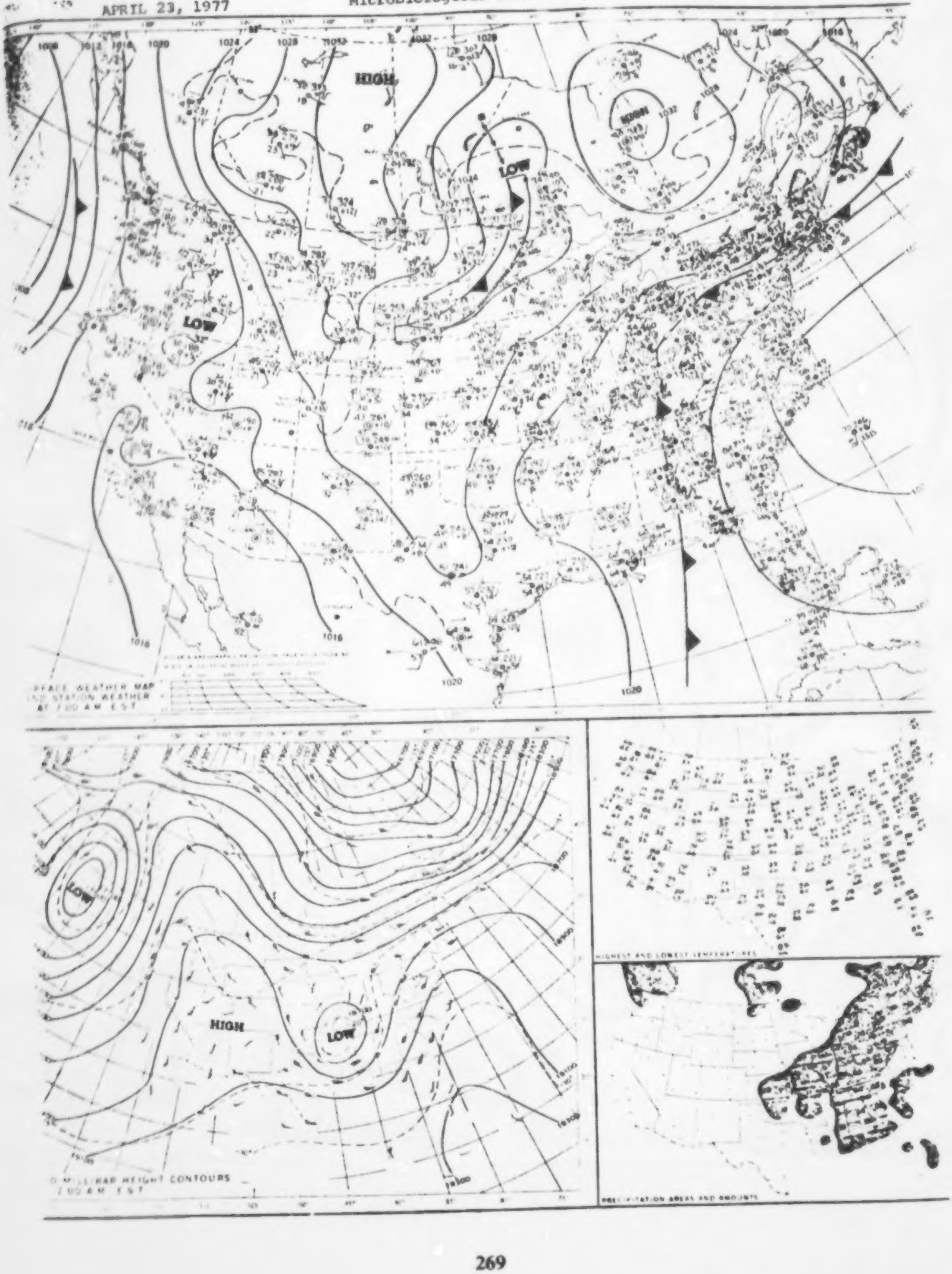
SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

APRIL 23, 1977 Microbiological Trial # 36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LOW
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HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

SYNOPTIC REGIME NO.3

Virus Trials # I1, I3-I6, II1-II6

Microbiological Trials # 11-17, 22-30, 33, 34, 37, 38

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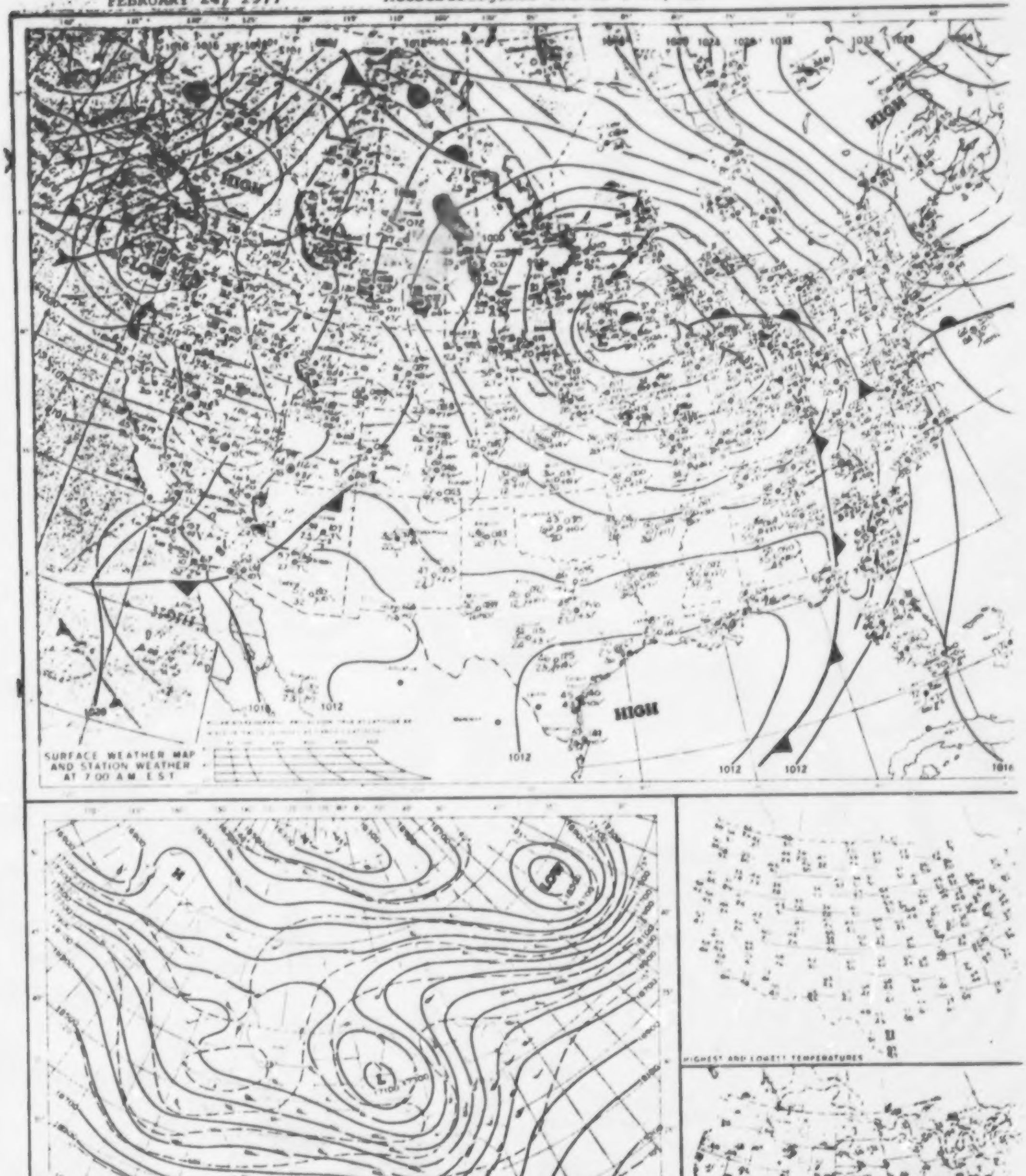
FEBRUARY 24, 1977 Microbiological Trials # 11, 12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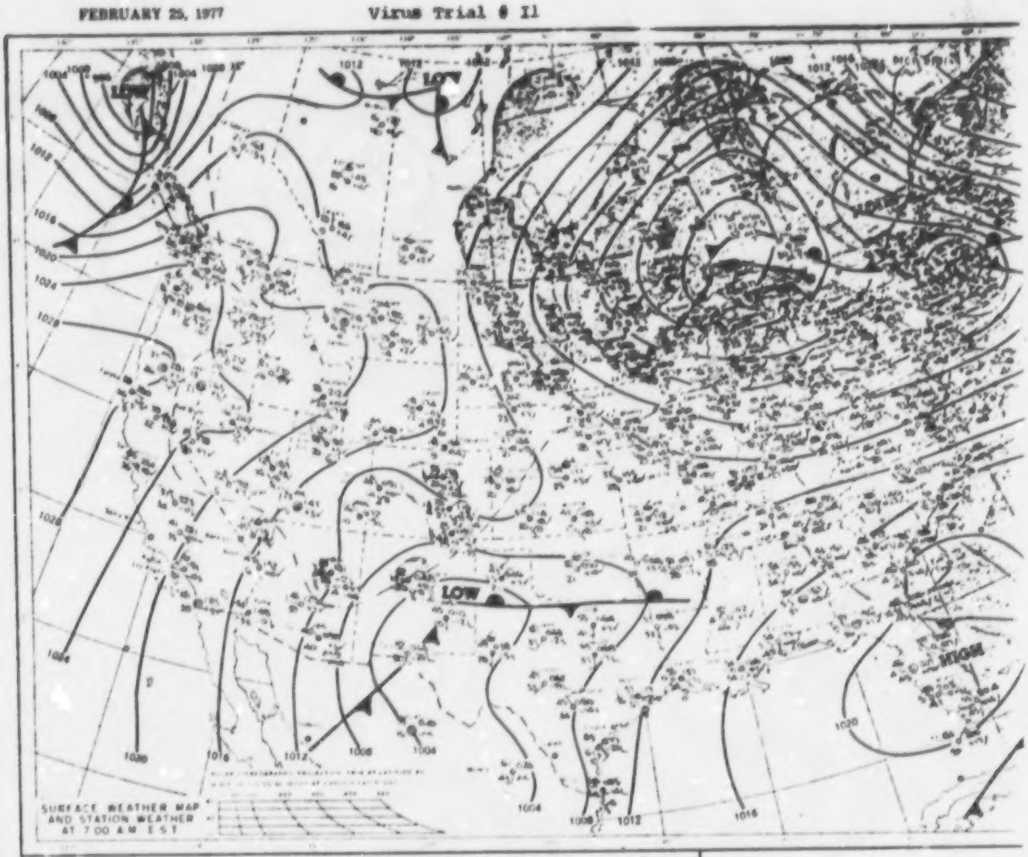
500 MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

FEBRUARY 25, 1977 Virus Trial # I1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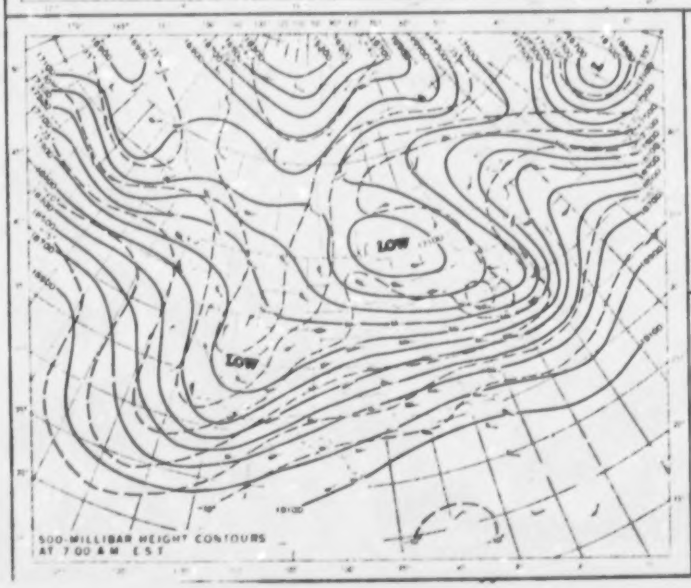
SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.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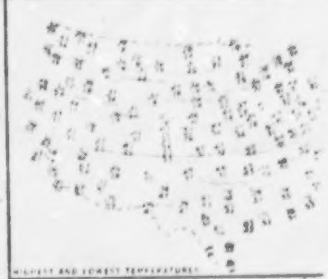
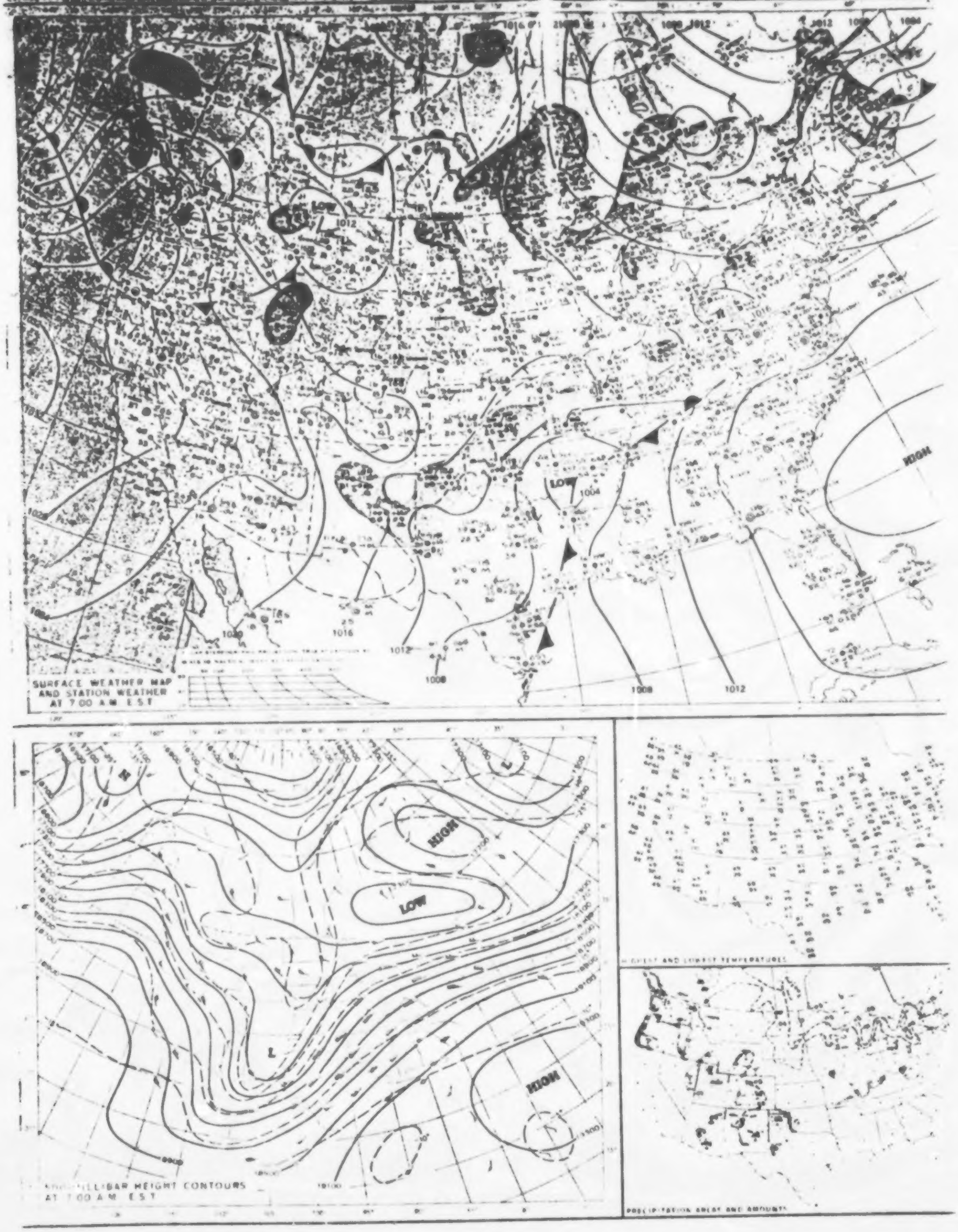

HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

FEBRUARY 26, 1977 Virus Trial # II-16


SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
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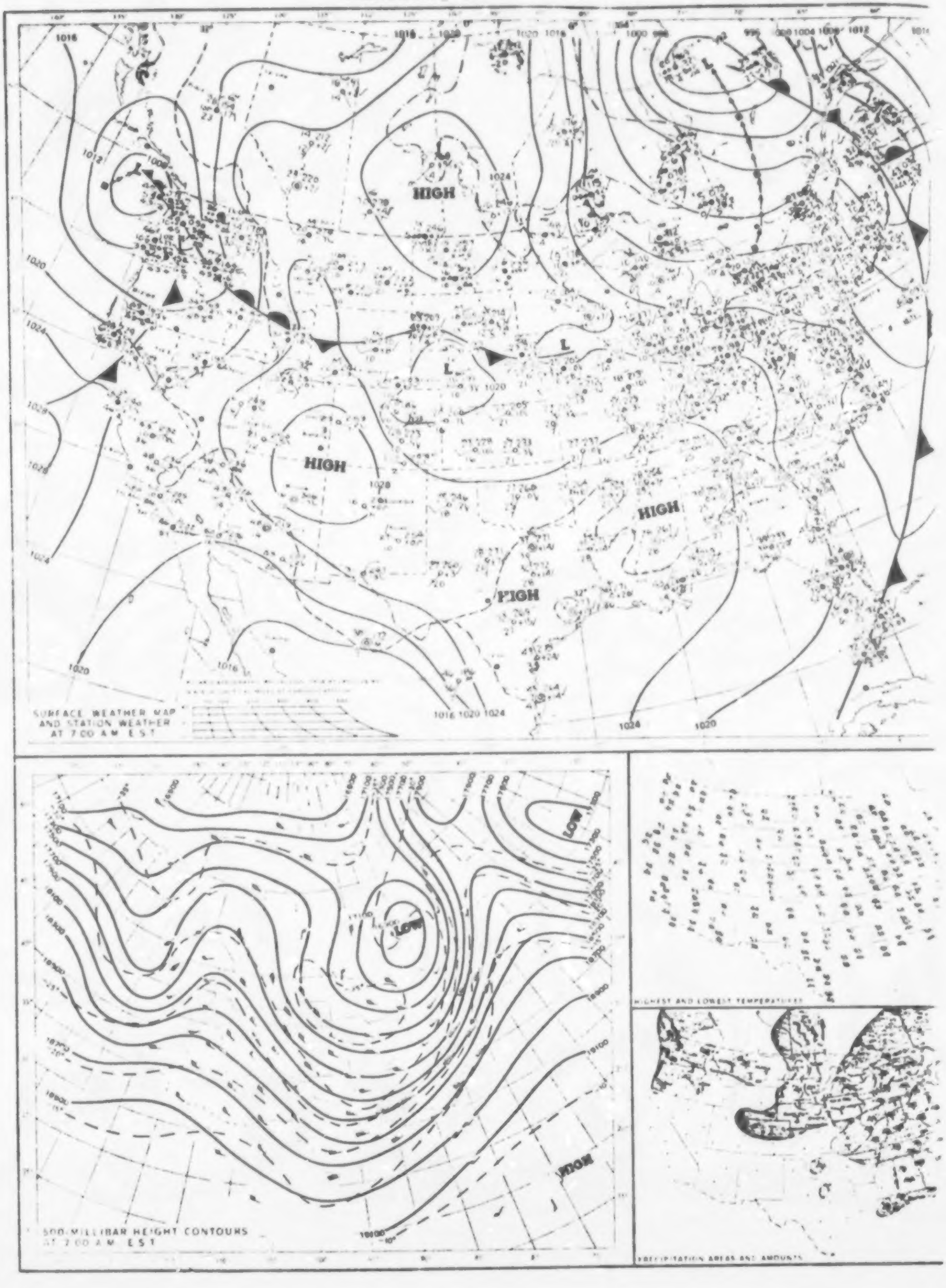
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

FEBRUARY 28, 1977 Microbiological Trial # 13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SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.

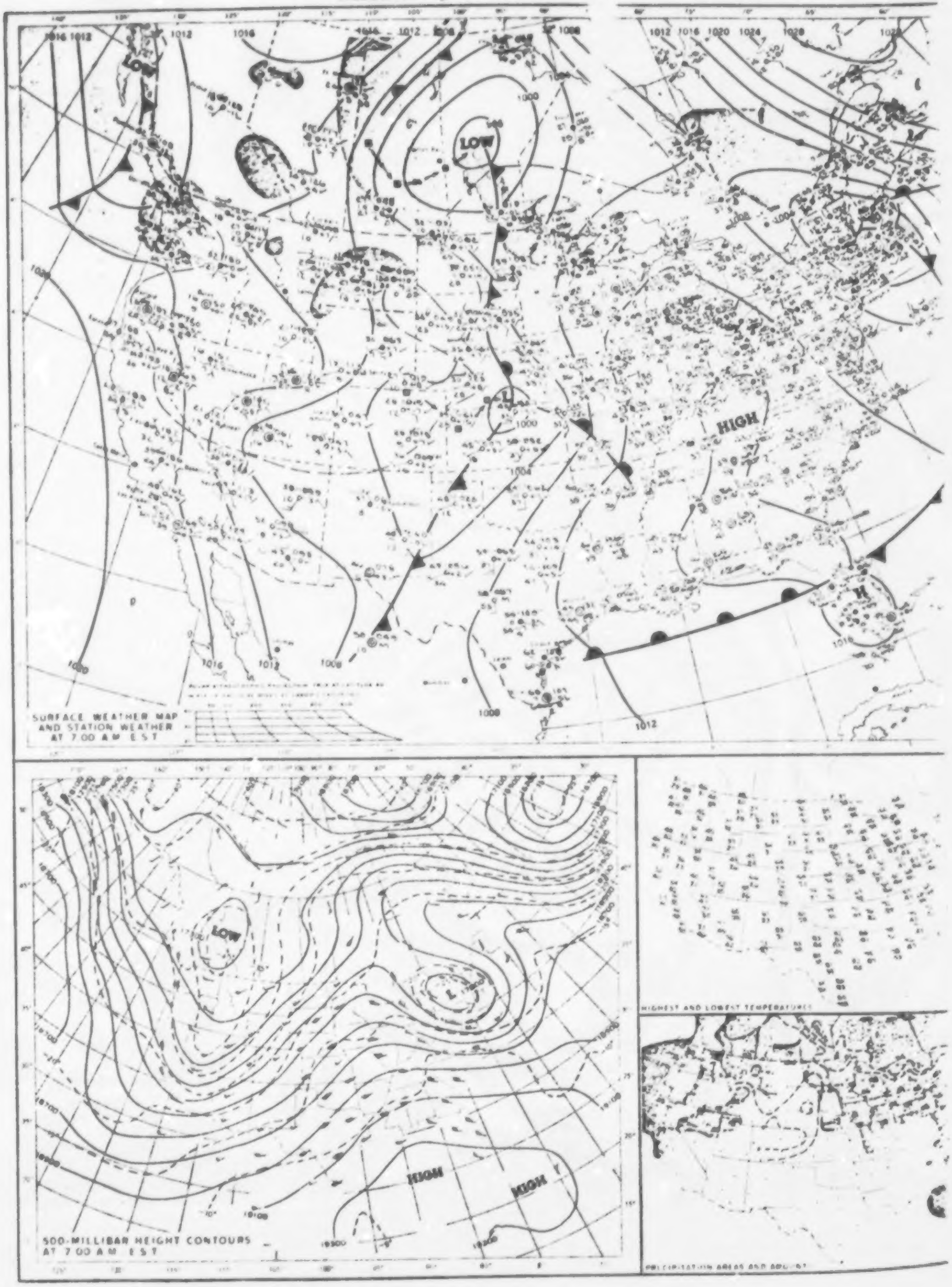
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.

HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

MARCH 14, 1977

Microbiological Trial # 1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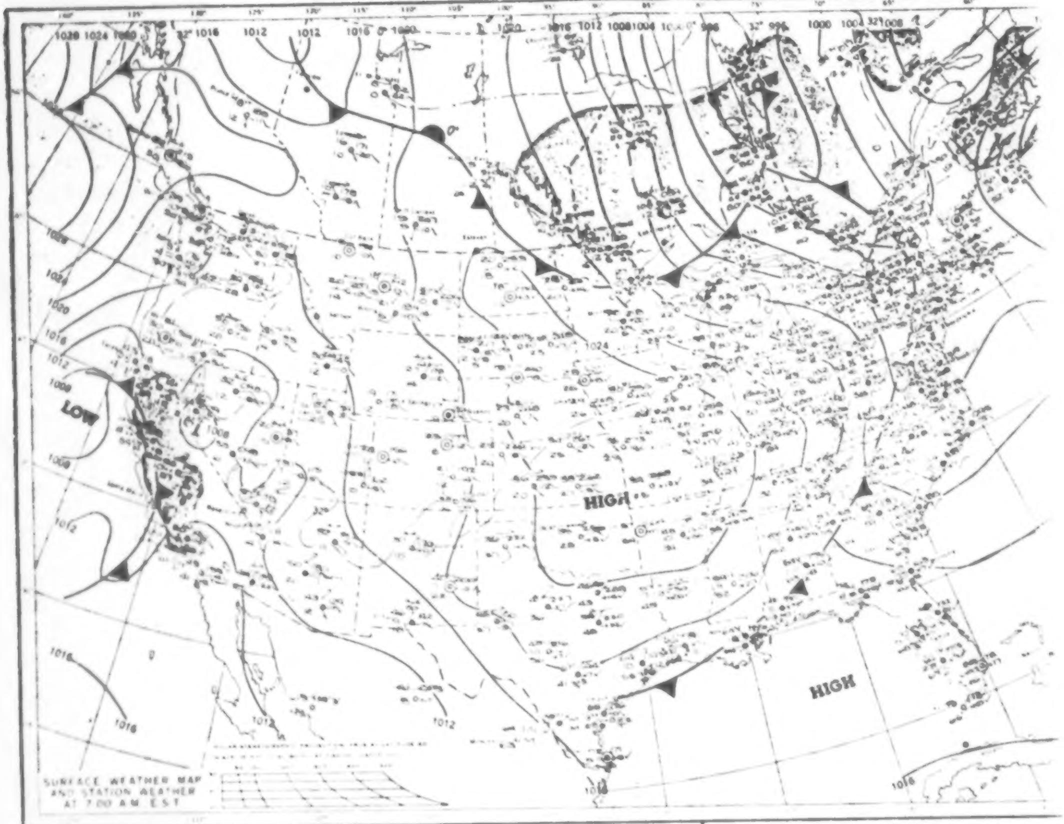
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

MARCH 16, 1977 Microbiological Trial # 15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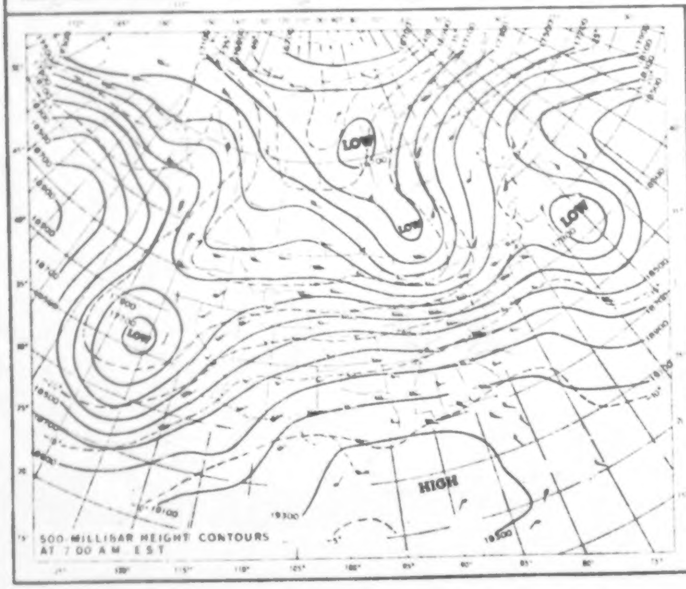
SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.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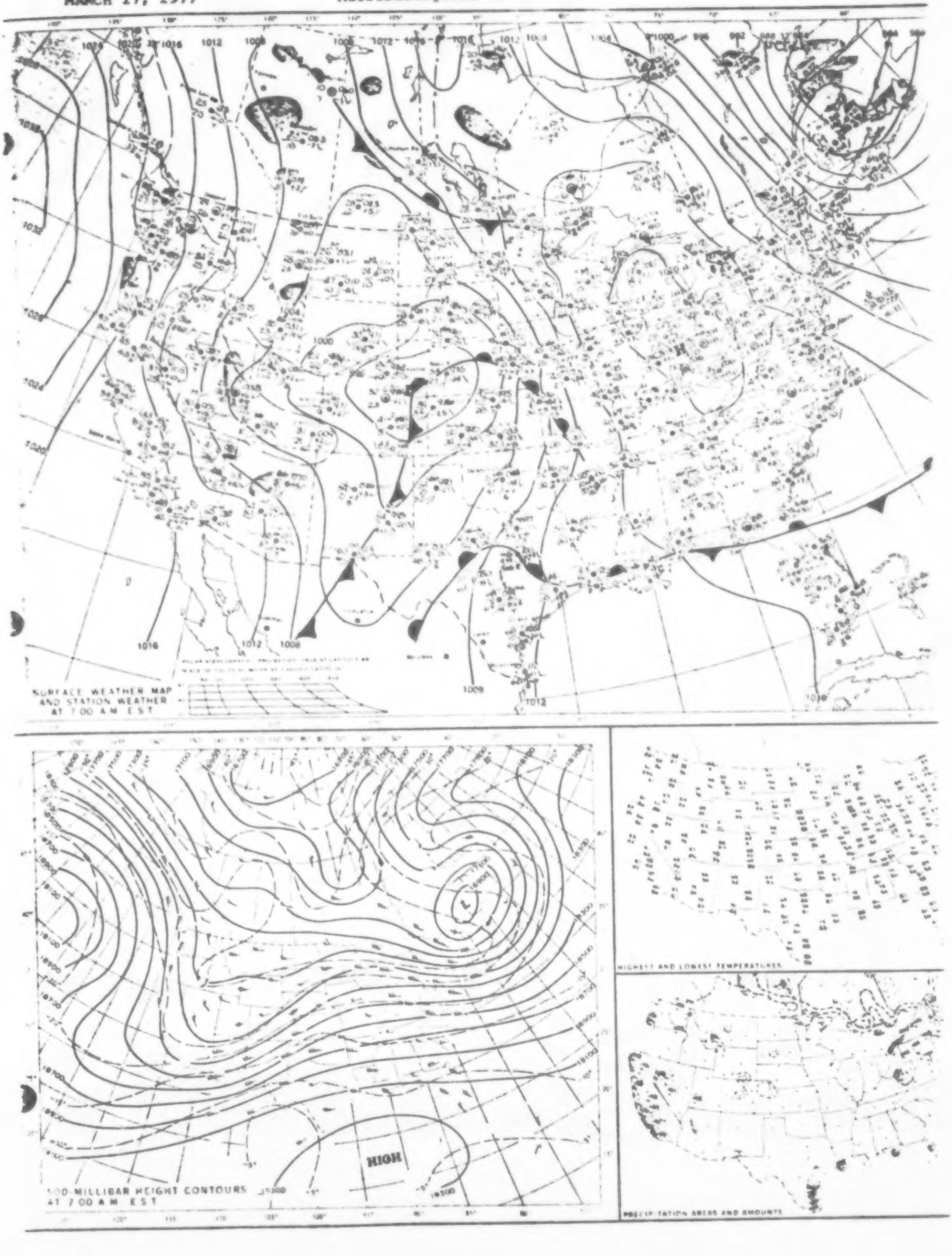
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.

HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

MARCH 17, 1977 Microbiological Trial # 16


SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
1016
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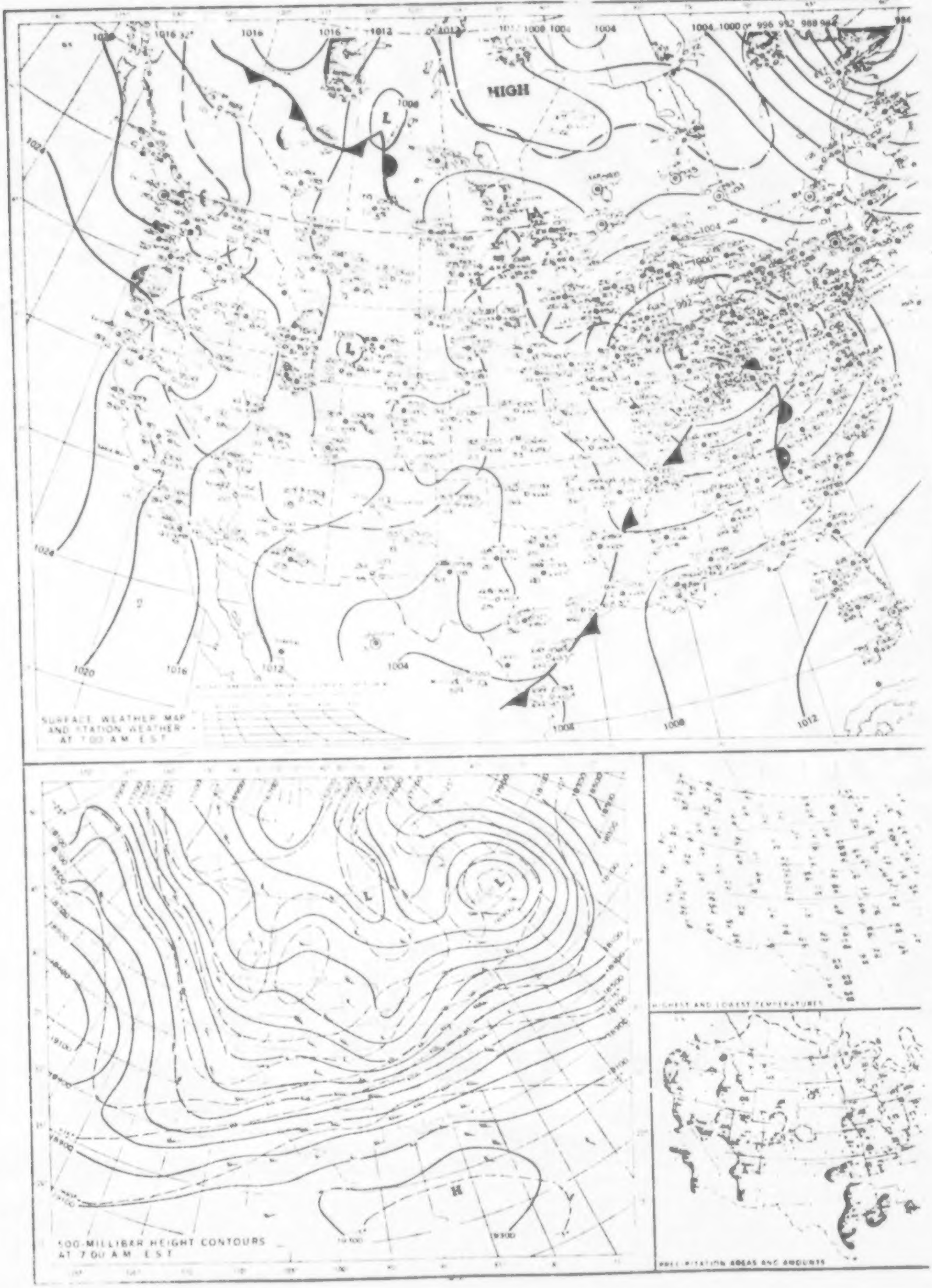
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGH
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

MARCH 18, 1977 Microbiological Trial # 17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SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
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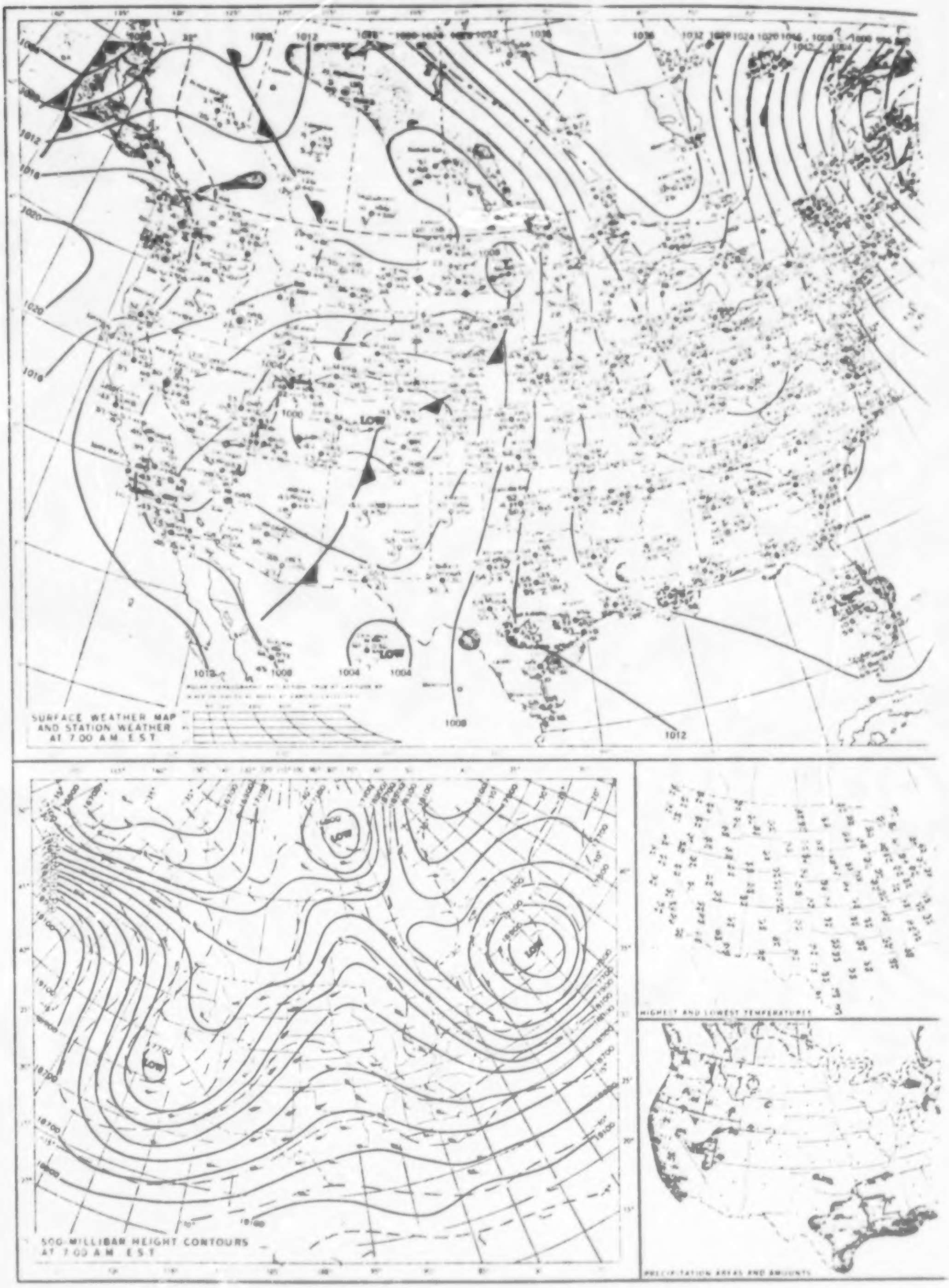
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

MARCH 25, 1977 Microbiological Trial # 22


SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
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500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
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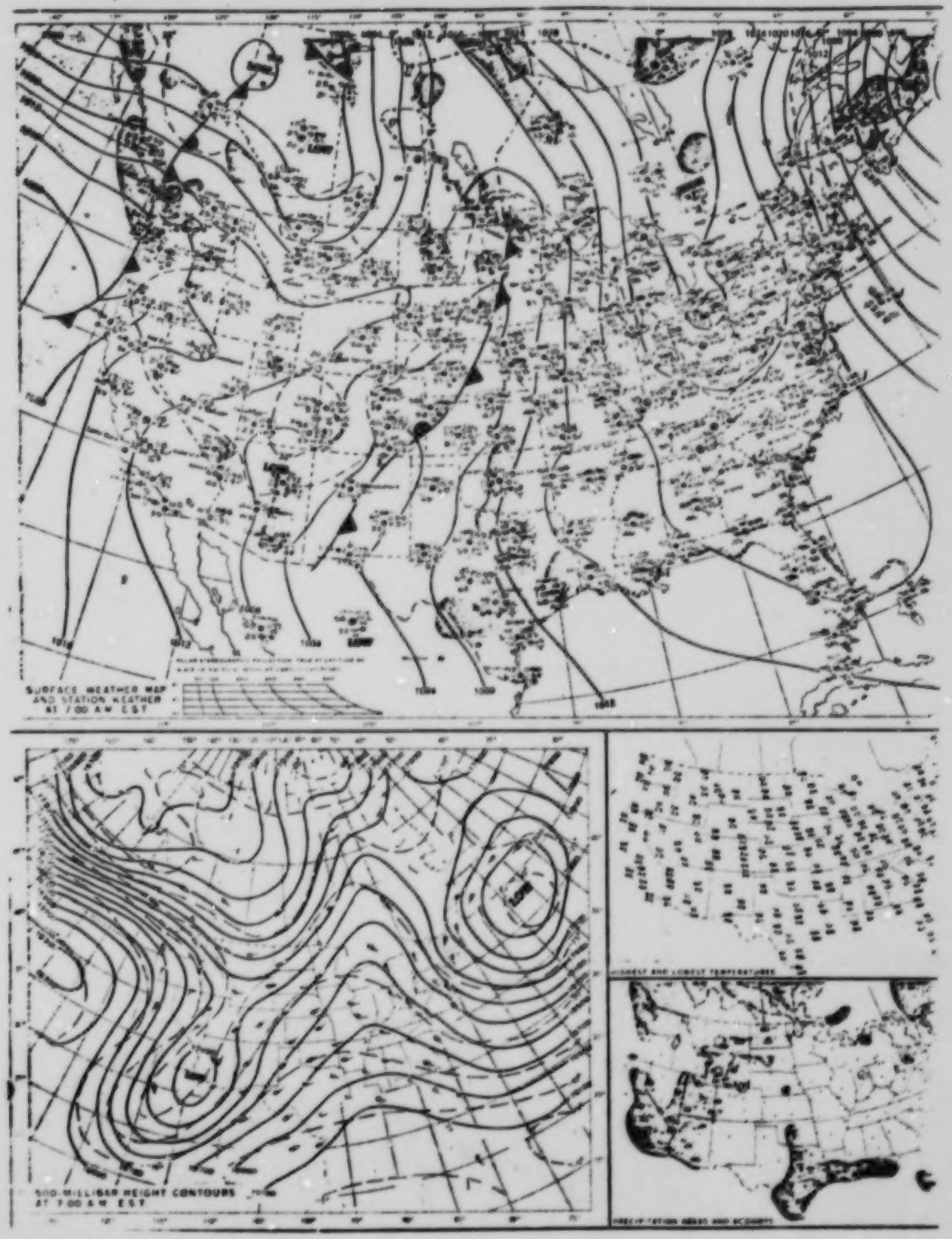
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

MARCH 26, 1977   Microbiological Trials # 23, 24



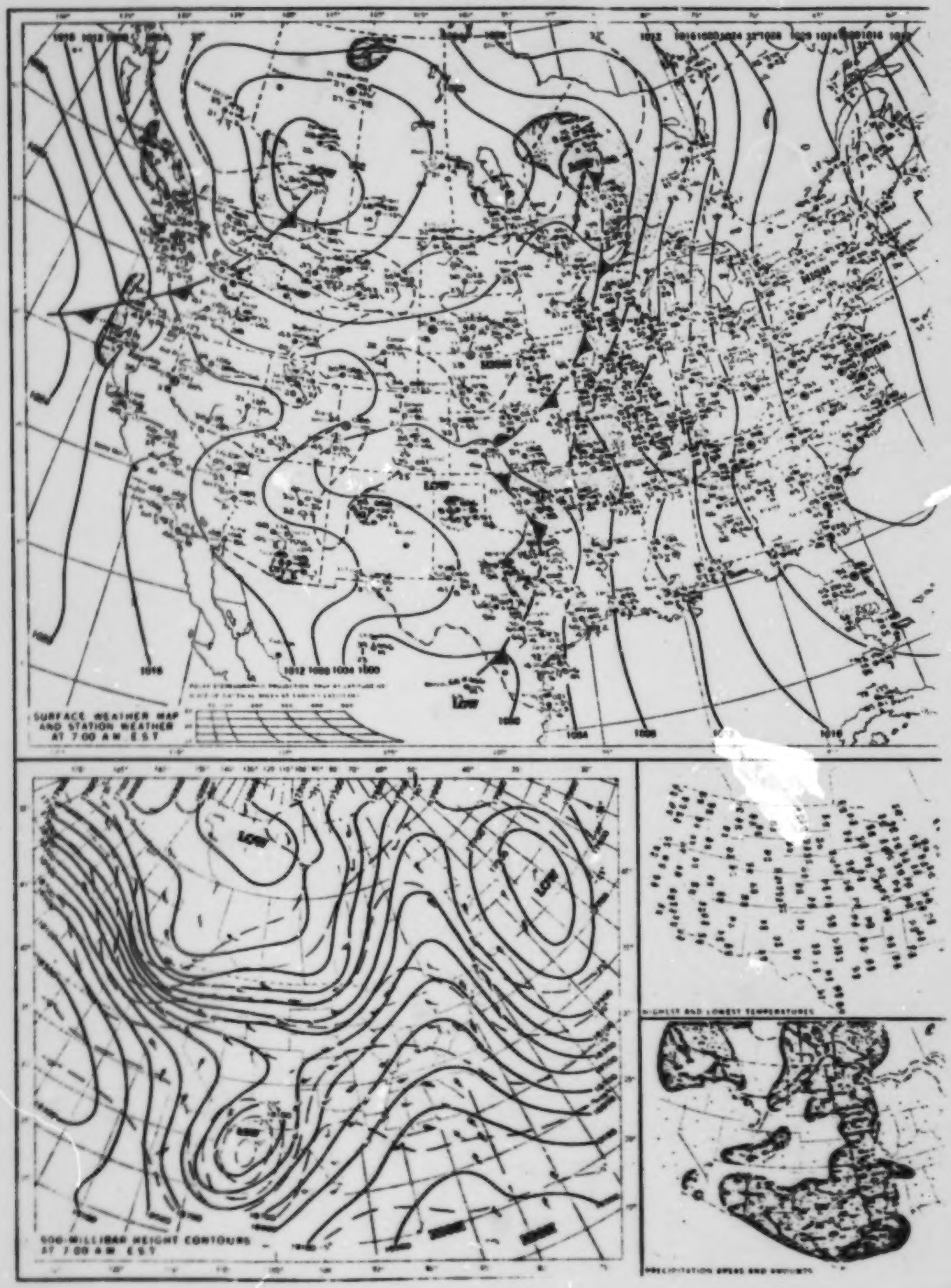
SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.

500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.

HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

MARCH 27, 1977 Microbiological Trials # 25, 26


LOW
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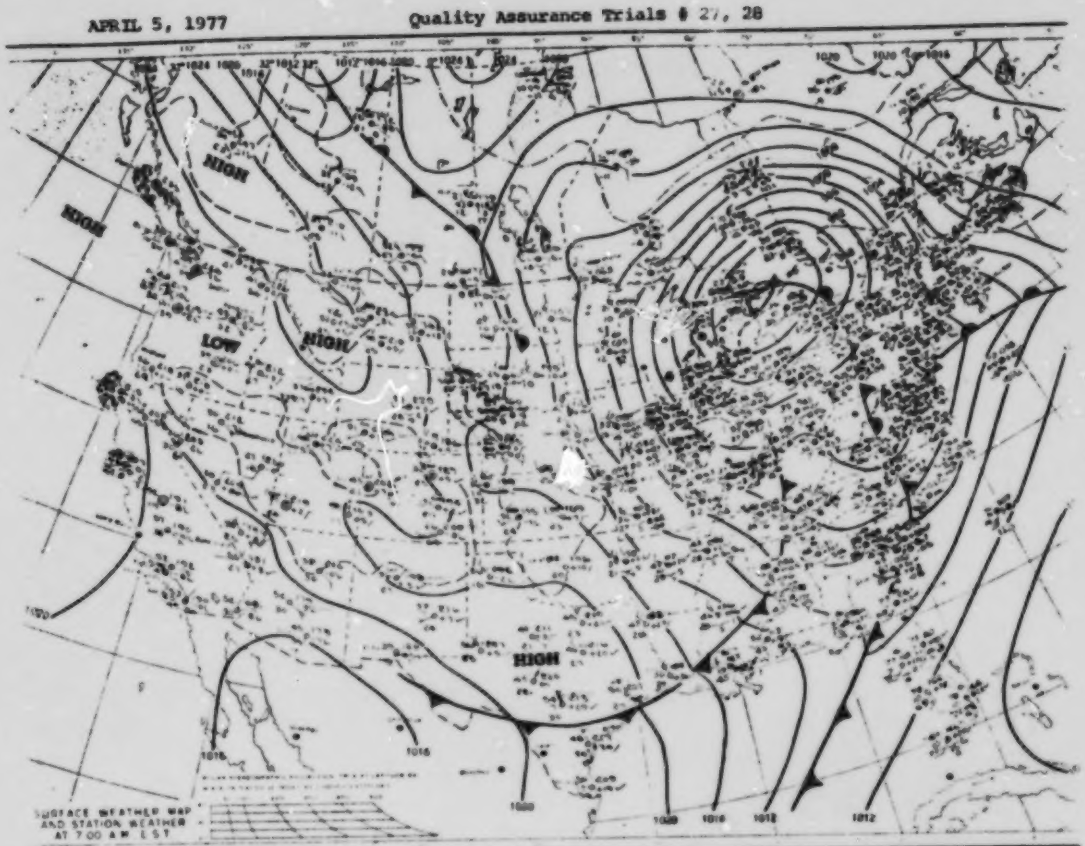
HIGH
SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
LOW
LOW
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

APRIL 5, 1977 Quality Assurance Trials # 27, 28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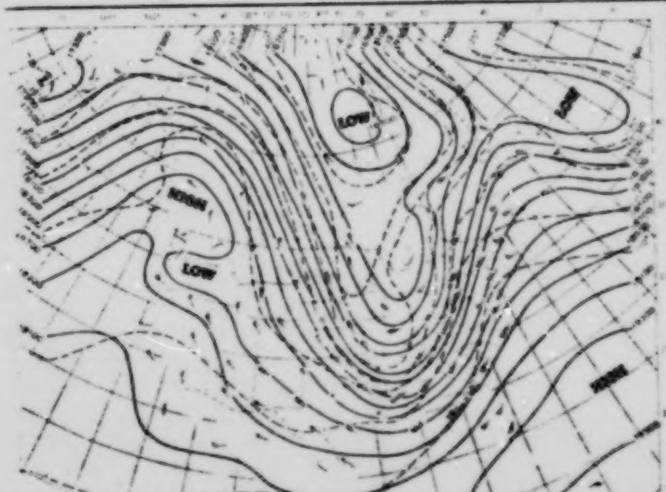
SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.

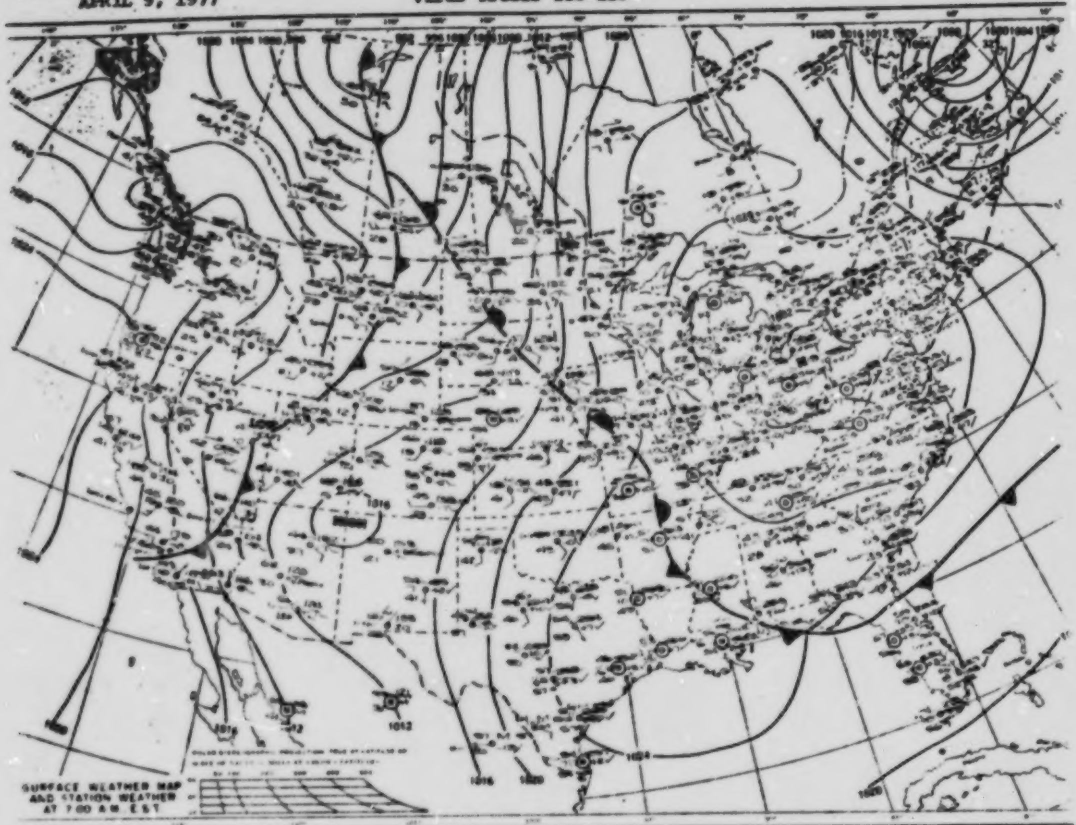


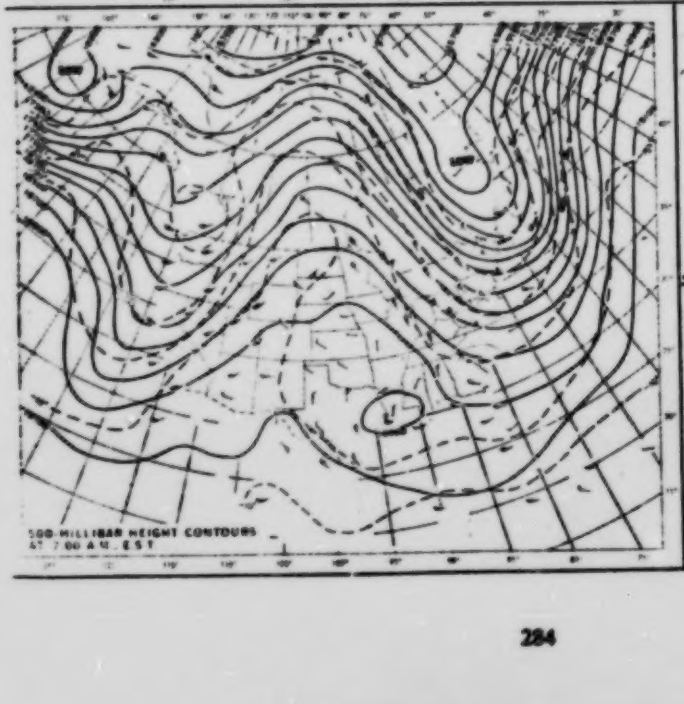
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.

HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

APRIL 9, 1977 Virus Trials 111-116


SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.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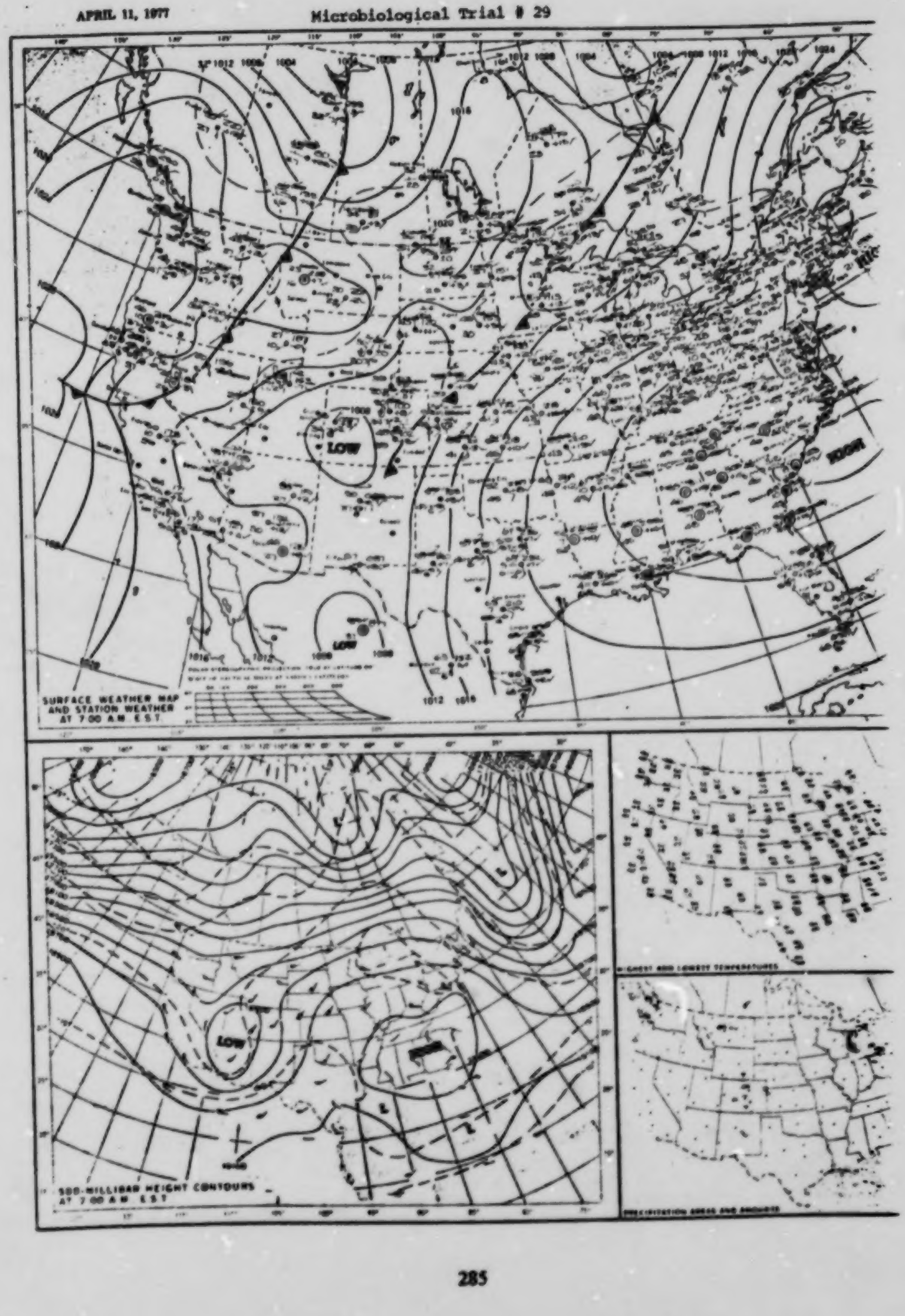
HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

APRIL 11, 1977 Microbiological Trial # 29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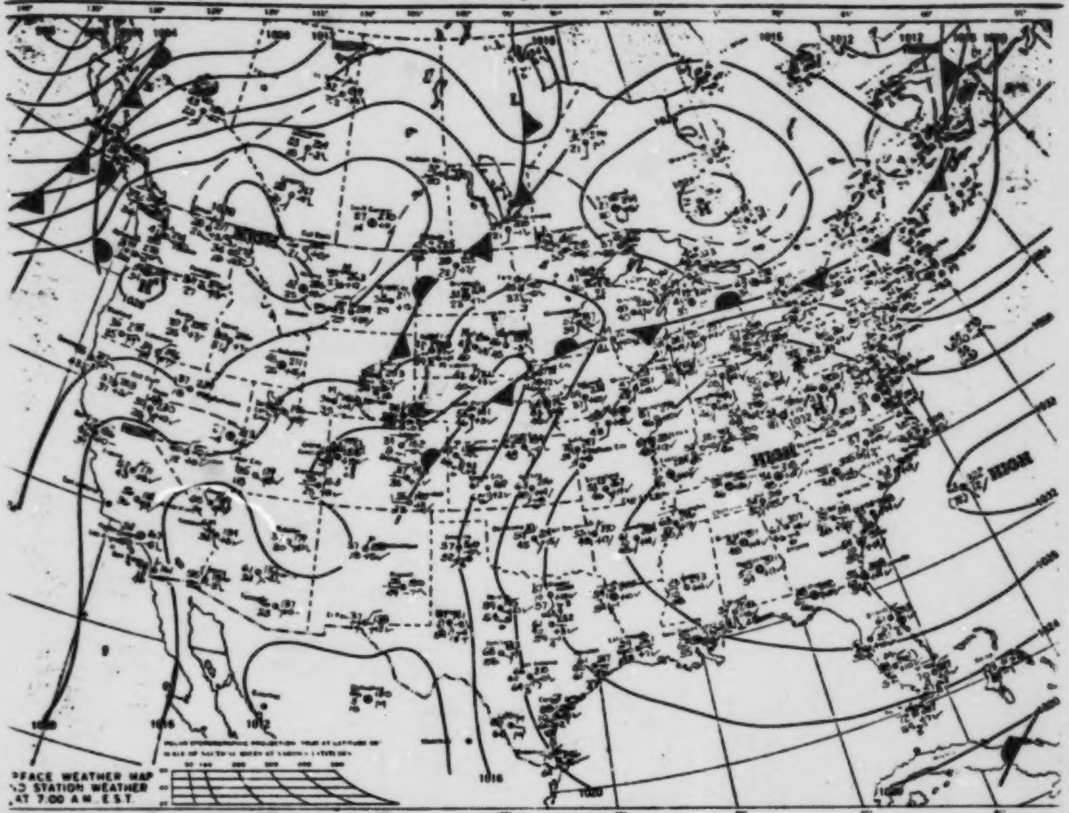
SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES
PRECIPITATION AREAS AND AMOUNTS

APRIL 12, 1977 Microbiological Trial # 30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RFACE WEATHER MAP
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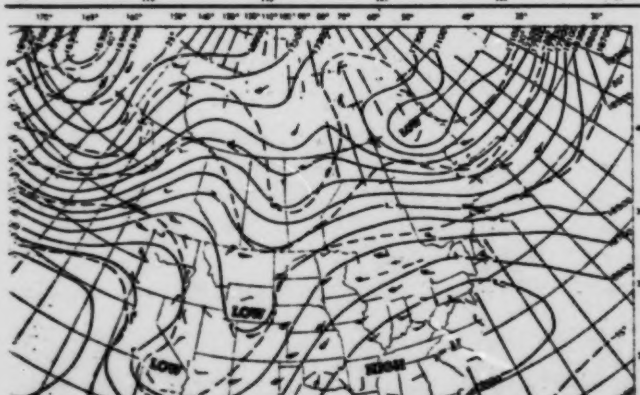
AT 7:00 A.M. E.S.T.


LOW
LOW
LOW
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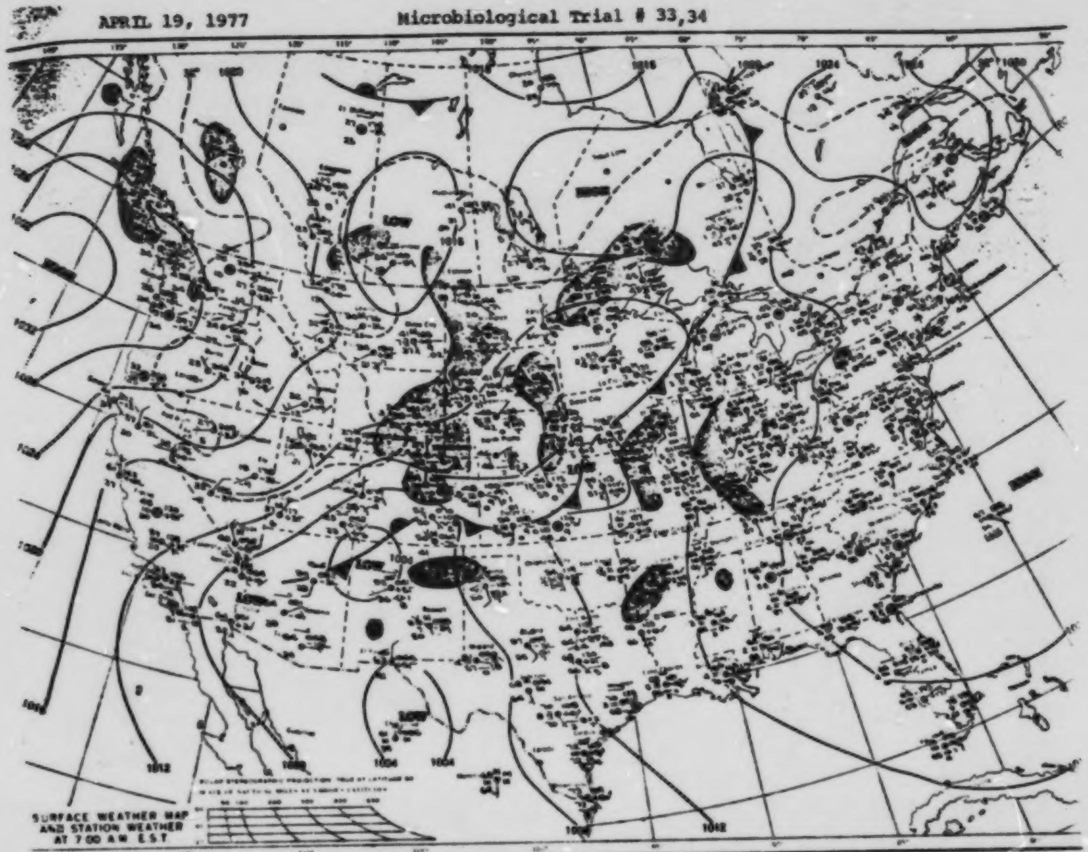
0-MILLIBAR HEIGHT CONTOURS
7:00 A.M. E.S.T.

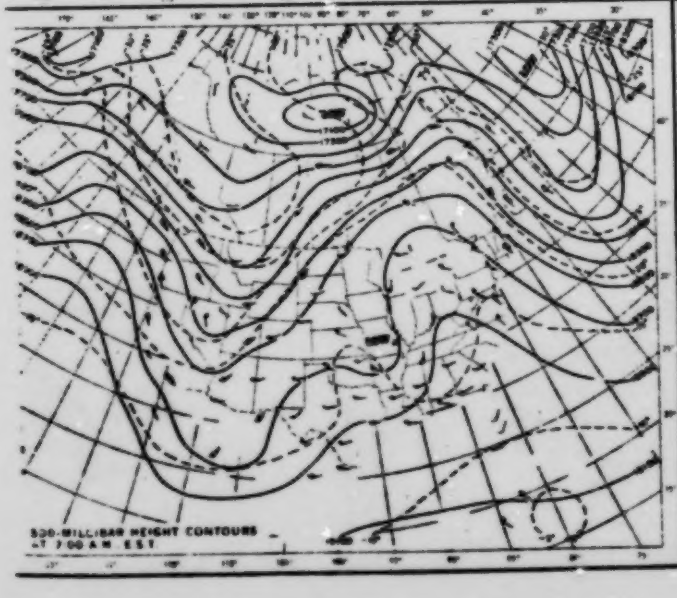
HIGHEST AND LOWEST TEMPERATURES

PRECIPITATION AREAS AND AMOUNTS

APRIL 19, 1977 Microbiological Trial # 33,34

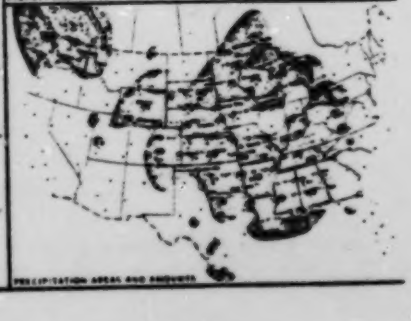


SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. EST



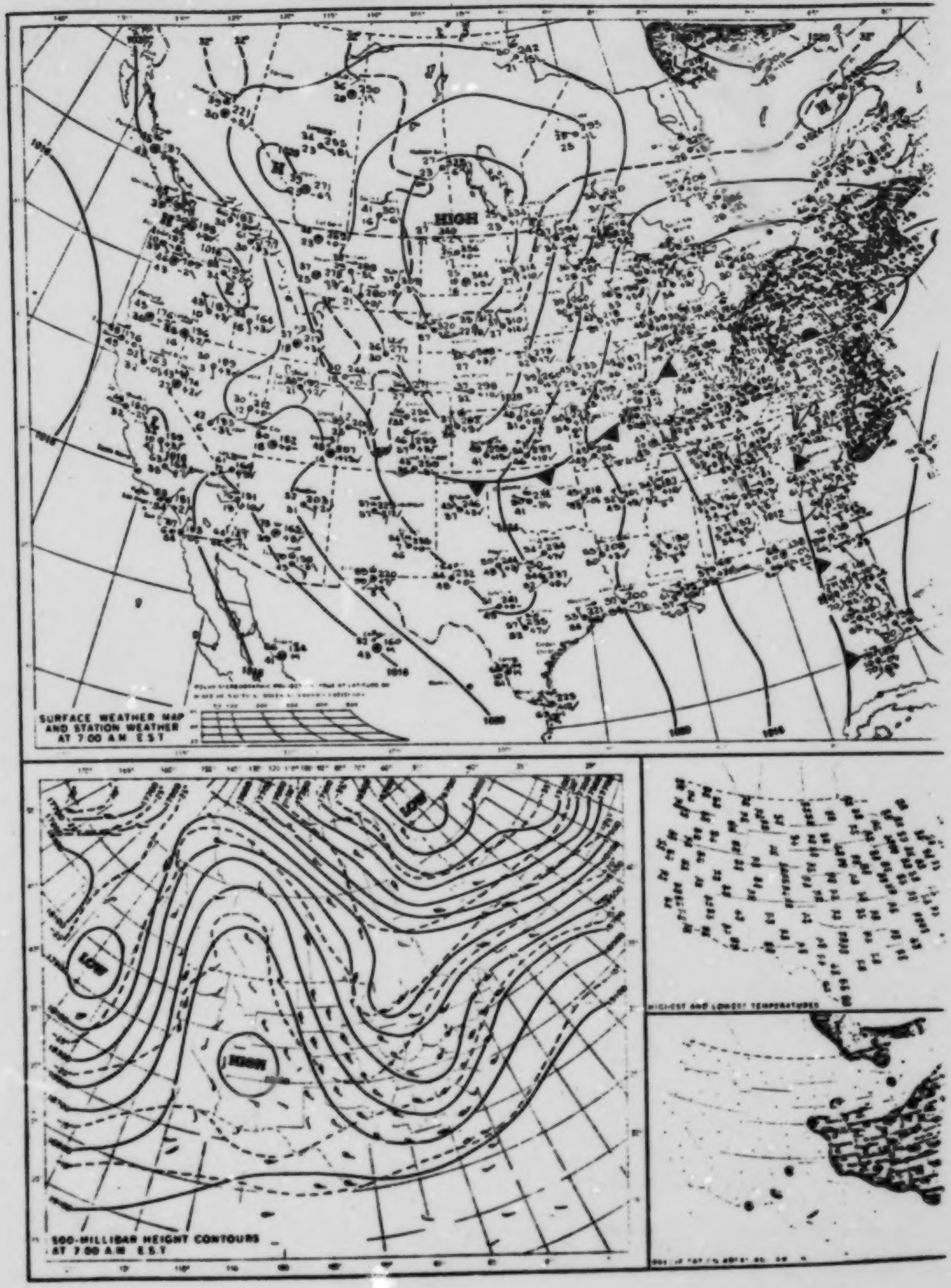
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. EST

HIGHEST AND LOWEST TEMPERATURES



PRECIPITATION AREAS AND AMOUNTS

APRIL 24, 1977 Microbiological Trials # 37, 38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SURFACE WEATHER MAP AND STATION WEATHER AT 7:00 A.M. E.S.T.
LOW
HIGH
500-MILLIBAR HEIGHT CONTOURS AT 7:00 A.M. E.S.T.
HIGHEST AND LOWEST TEMPERATURES

APPENDIX D
METHODS AND MATERIALS

APPENDIX D
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APPENDIX D METHODS AND MATERIALS

A. Sample Collection and Handling Methods

1. Meteorological Measurements and Instrumentation

Simultaneous meteorological measurements were made at the two- and ten-meter heights during both Pre-Fair and Post-Fair at the location shown in Figure IV.B-1. The following parameters were measured at the two-meter level; wind velocity and direction, temperature, relative humidity and precipitation (amount, rate and duration). The following parameters were measured at the ten-meter level; wind velocity and direction and temperature. Atmospheric stability can be inferred from both the wind direction and temperature differences at the two levels. Wind velocities assist in determining the probable downwind and crosswind axes of the aerosol plume. The relative humidity provides a means of inferring chemical interaction between the effluent and atmospheric moisture. Precipitation measurements also assist in inferring the interaction and possible "wash-out" of the effluent from the atmosphere.

Measurements were made and recorded on time-referenced strip charts by mechanical weather stations manufactured by Meteorology Research, Inc. A guyed crank-up tower held the ten-meter level station whereas the two-meter station was located on a rigid tripod. This arrangement permitted easy access to the instrumentation for servicing and chart changing.

Starting threshold for both the anemometer and wind vane is less than three-fourths of a mile per hour. Wind direction measurement accuracy is ±1% of full scale while wind speed data are accurate to ±2%. Humidity measurements are accurate to ±3% over the entire range of humidities from 0 to 100 percent. Rainfall measurements are accurate within .01 inch per 2 inches of rainfall per hour. Temperature measurements are accurate to ±3°F absolute. However, the two temperature sensors were calibrated to each other against a standard thermometer traceable to NBS standards. Therefore, differences in temperatures of the thermometers—the criterion of interest to establish the atmospheric stability—should be accurate to within less than 1°F.

Wind direction measurements were also made in the immediate vicinity of the sampling site by use of an R.M. Young Model 6101 Portable Wind Set. This measurement was made only to determine the wind direction with respect to the actual orientation of the spray line.

The two- and ten-meter stations were found to be inadequate for obtaining the necessary information for dispersion modeling, so in August 1976, a 102-foot meteorological monitoring station was constructed on a one-acre site near the spray field operation. Figure IV.B-1 locates the site relative to the spray fields and surrounding area. This equipment was installed prior to Post-Fair aerosol sampling to provide extensive meteorological data to be used in developing aerosol dispersion models for spray irrigation systems. The field measurement locations during Post-Fair are summarized in Figure V.A-1.

The tower and associated equipment were provided on a loan basis from the U. S. Army, Dugway Proving Grounds, Dugway, Utah. The tower was an Up-Right Stairway-Type Tower built by Up-Right Scaffolds and consisted of 17 six-foot collapsible sections. The sensors for collecting meteorological data were placed on the tower at the positions indicated in Table D-1.

Instrumentation for recording information from the sensors consisted of two systems in parallel circuits: a MINIDAS tape system and a strip chart recording system. The MINIDAS system had the capability

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Table D-1
SENSOR POSITIONS ON 102—FOOT METEOROLOGICAL TOWER

Nominal Level	Sensor Type	Actual Level
4 m.	Temperature, Dew Point	2.0 m.
4 m.	Wind Speed, Wind Direction	3.7 m.
8 m.	Temperature, Dew Point	7.7 m.
16 m.	Temperature, Dew Point	16.4 m.
16 m.	Wind Speed, Wind Direction	15.9 m.
32 m.	Temperature, Dew Point, Wind Speed, Wind Direction	30.7 m.

of scanning the sensor points on the tower at any given time interval and recording the data from the sensors on an IBM magnetic tape. The recording unit recorded only when the MINIDAS system scanned the sensors on the meteorological tower. Tapes were decoded by Dugway Proving Grounds.

The strip chart recorders provided data from the tower sensors on a continuous basis, independent of the MINIDAS system. Eight recorders were used with the configuration given in Table D-2. The recorders used for temperature and dew point were connected to a scanning transmitter at the base of the tower which transmitted measurements for each level at any given time interval. Therefore, temperature and dew point recorders recorded their respective parameter at all levels, but only one level at a time.

Table D-2
STRIP CHART RECORDER UNITS ON 102—FOOT METEOROLOGICAL TOWER

Strip Chart Recorder Unit	Recording Range
4 m wind speed	0-20 m/s
4 m wind direction	0 - 540°
16 m wind speed	0-20 m/s
16 m wind direction	0 - 540°
32 m wind speed	0-20 m/s
32 m wind direction	0 - 540°
Temperature	0 - 100°F
Dew Point	0 - 100°F

For measuring wind speed and wind direction above the 32-meter level, Dugway Proving Grounds also loaned the necessary equipment for Pibal Balloon plotting. In addition to a balloon theodolite, helium, 30-gram balloons, pibal data sheets, plotting board and lights and parachutes for night tracking were provided.

Field measurements of solar radiation were recorded by a Belfort Pyrheliograph No. 5-3850 with a range of 0 to 3 gram-calories per square centimeter per minute. A Bendix Model 566-2 portable, battery aspirated psychrometer was used to observe wet- and dry-bulb temperature readings both upwind and downwind of the spray line.

In addition, relative humidity readings were obtained through the cooperation of the Lawrence Laboratory at Livermore, CA. These were coordinated with the day and time of each aerosol run and were used in the development of the microbiological dispersion model.

2. Wastewater Sampling Methods

a. *Daily Composite Samples*

During Pre-Fair, a daily composite effluent sample was collected during the hours that wastewater was pumped from pond 2 to the spray fields. The sample was taken by a Sigmamotor Sampler Modified Model WM-5-24-R from an overflowing bucket of the wastewater from the pump discharge. The composite sample consisted of 300 ml collected in a 20-liter carboy every 15 minutes. The carboy and sample were maintained at 4°C in a refrigerator located below the sampler. After every sampling period, the automated sampler purged the collecting tube between the sampling point and the carboy. Every morning before spraying commenced, the collected sample was removed and an empty sterilized carboy was placed in the refrigerator for the next daily composite sample.

In the SwRI field facility, the composite sample was divided into the appropriate-size labeled containers and, if required, were preserved according to the following scheme:

Constituent	Preservative
pH	none; analysis on site
chlorine (free)	none; analysis on site
chlorine (total)	none; analysis on site
total organic carbon (TOC)	cool (4°C); H_2SO_4 to pH <2
solids (suspended)	cool (4°C)
solids (total)	cool (4°C)
nitrogen series	
nitrate	cool (4°C); H_2SO_4 to pH <2
nitrite	cool (4°C)
ammonia	cool (4°C); H_2SO_4 to pH <2
organic nitrogen	cool (4°C); H_2SO_4 to pH <2
phosphorus	cool (4°C)
BOD	cool (4°C)
COD	H_2SO_4 to pH <2
hardness	cool (4°C)
biological samples	cool (4°C)

Before shipment, all samples were placed in an ice bath for 45-50 minutes to assure that sample temperature would remain at 4°C during shipment. Samples designated for UTSA were shipped, in a styrofoam mailer with one frozen Kool-Pac®, on a nonstop four-hour morning flight from San Francisco International Airport. Samples designated for local laboratories were personally delivered between 8 and 9 AM to assure timely performance of the analyses. The composite wastewater sampling program was discontinued during Post-Fair.

b. *Grab Samples*

Three types of effluent grab samples were taken during the study.

1) Pond—Chlorine. A grab sample (500 ml) was collected daily from pond 2 near the pumping station for the routine analysis for free and total chlorine.

2) Pond—Pathogen Screen. On a weekly basis a large-volume grab (LVG) was collected for microbial characterization. This 20-liter sample was collected in a large sterile carboy with a small portable pump that was placed just below the pond surface near the inlets to the pumps. These samples were taken in the early morning prior to daily activation of the pumps. Aliquots were transferred into 12 one-liter bottles, cooled to 4°C, and shipped for analysis on the same day as collection. Seven samples were collected in the same manner for microbial characterization during Pre-Fair. During Post-Fair only one large-volume grab was collected for microbiological characterization. Before Post-Fair (Aug. 23, 1976), one 20-liter large volume grab sample was collected for a special respiratory virus screen. Aliquots were transferred into 12 one-liter bottles, frozen, and shipped in dry ice. Other aliquots were transferred into 6 one-liter bottles, cooled to 4°C, and shipped for analysis as above.

3) Spray line. During both Pre- and Post-Fair, a sample of sprayed effluent was collected at one end of the spray line during each aerosol run. A faucet was connected to the stanpipes at the end sprinklers to which a 50-foot 5/8-inch diameter hose was attached. By restricting the flow at the end of the hose with a valve, it was possible to collect a large sample (15 to 20 liters) in a 5-gallon sterile carboy during the aerosol sampling run. After agitation, aliquots of this sample were placed in appropriate-size labeled containers for shipment and subsequent analysis. For the Post-Fair wastewater grab samples at the sprayer head, a Y connector was used at the end of the hose instead of the valve. One side of the outlet side of the Y was connected to an orifice, sized to provide about 12 liters of effluent during the 30-minute aerosol sampling period. The other side flowed continually at a high rate allowing a more representative sample to be obtained during the aerosol run from the restricted side.

A total of seven 20-l grab samples were collected during the Pre-Fair study for microbial characterization. The sampling schedule was spread out over a seven-week period with the samples being collected on a different day of the week each week. An eighth sample was collected well after the Alameda County Fair, August 23, 1976, to replace the second large-volume sample collected which was not completely analyzed due to unforeseen difficulties in the analytical laboratory. In addition to these large-volume samples, three of the regular composites were also subjected to the pathogen screen.

A single 20-l grab sample was collected during the first week of the Post-Fair study for pathogen screen. The method of collection was the same as that used in Pre-Fair. No other pathogen screens were performed during Post-Fair.

One aerosol pathogen screen was performed during Phase II. The aggregated 20-l sample from all aerosol samples in Pre-Fair aerosol Run 36 was analyzed for each of the bacteriological groups used in characterization of the large-volume grab effluent samples.

3. Aerosol Sampling Methods

a. High-Volume Samplers for Microorganism Aerosols

(1) Description of Samplers

Two types of high-volume air samplers were used for collecting biological aerosols. The first type was the LEAP sampler, Model 3440, manufactured by the Environmental Research Corporation of St. Paul, Minnesota; the second type was the Litton Model M Large-Volume Air Sampler, manufactured by Applied Science Division, Litton Systems, Inc., Minneapolis, Minnesota.

Both samplers are designed to collect airborne particles and concentrate them into a thin, moving film of liquid. The nominal flow rate for the samplers is 100 l per minute.

The LEAP sampler manual describes the module as shown schematicaly in Figure D-1. Air enters the sampler module through a ceramic nozzle and then passes through the center of an attached high-voltage plate. The air then flows radially outward between this high-voltage plate and a rotating collection disc which is maintained at ground potential. It is then exhausted from the sampler by the blower.

"A ring of stainless steel needles, located on the high voltage plate and concentric with the air inlet, emit a continuous negative corona. As airborne particles pass through this corona, they are electrically charged and the high potential maintained across the plate-to-disc spacing precipitates the charged particles onto the collection disc."

"One channel of the peristaltic pump supplies liquid from an external reservoir to the center of the rotating collection disc. Centrifugal force causes the liquid to flow as a thin, continuous film to the edge of the disc where it is collected by a static pickup. The particle-laden liquid is then pumped from the static pickup to an external reservoir by the second channel of the peristaltic pump."(82)

"The Litton Model M Sampler is designed to continuously collect particulate matter from a large volumetric flow rate of air (approximately 1000 liters/minute) and deposit it into a small amount of liquid (flow rate of 2ml/min). This effects a volumetric concentration factor on the order of 5×10^5 . Basically, the sampler is an electrostatic precipitator of a rather unusual configuration. With reference to the schematic diagram, Figure D-2, and an interior view, Figure D-3, aerosol is drawn into the unit through a converging nozzle and passes through the center of the high-voltage plate. It then flows radially between this plate and a lower rotating collection disc. An electric potential of 15,000 volts, which is maintained across a 11/16-inch spacing between the plate and disc, creates two effects: (1) A corona is emitted from a ring of 60 needles that is located concentric to the air inlet. Particles, exposed to air ions created from the corona, acquire an electrical charge. (2) The electric field provides the driving force to precipitate charged particles onto the lower disc."

"Liquid is pumped onto the center of the collection disc and, because of the centrifugal force, forms a thin moving film over the entire disc surface. Particles collected on the film are transported to a rotating collection ring where the liquid is removed by the pickup. Subsequently, the liquid drips into the collection funnel where it is pumped to a receiver located outside the sampler."

"To accommodate a broad range of sampling situations, several variable features are incorporated into the unit. These are:"

Air Flow Rate	**400 to 1200 liters/minute**
Liquid Flow Rate	**0 to 8ml/minute**
Disc Speed	**0 to 4500 rpm**
High Voltage	**0 to 20 kilovolts**

"When the sampler is in operation, the air flow rate is read directly from a calibrated meter on the front panel and is adjusted with a blower control potentiometer (see Figure D-4). Both disc speed

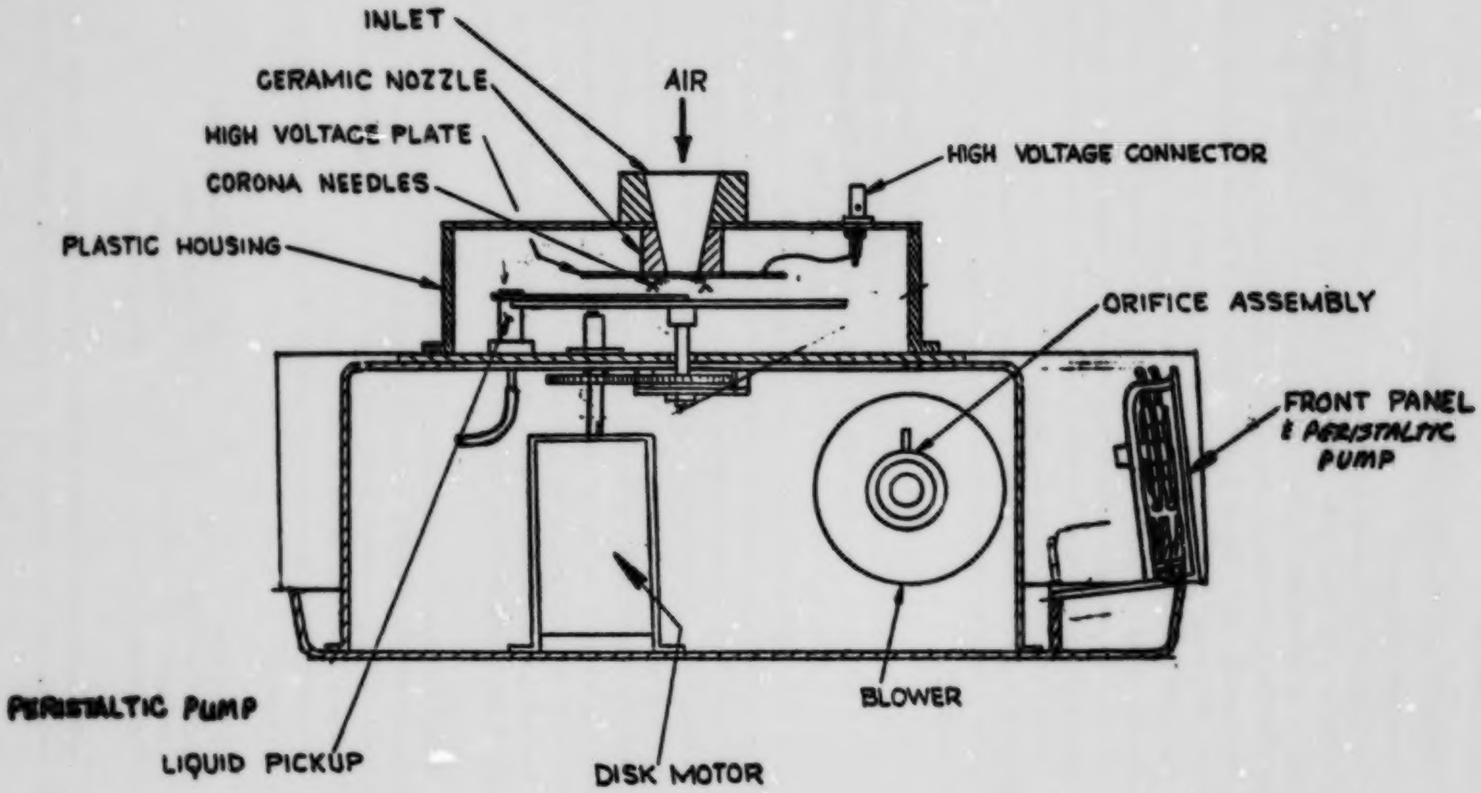
INLET
AIR
CERAMIC NOZZLE
HIGH VOLTAGE PLATE
CORONA NEEDLES
PLASTIC HOUSING
HIGH VOLTAGE CONNECTOR
ORIFICE ASSEMBLY
FRONT PANEL
& PERISTALTIC
PUMP
PERISTALTIC PUMP
LIQUID PICKUP
DISK MOTOR
BLOWER

Figure D-1
SCHEMATIC DIAGRAM OF LEAP SAMPLER MODULE

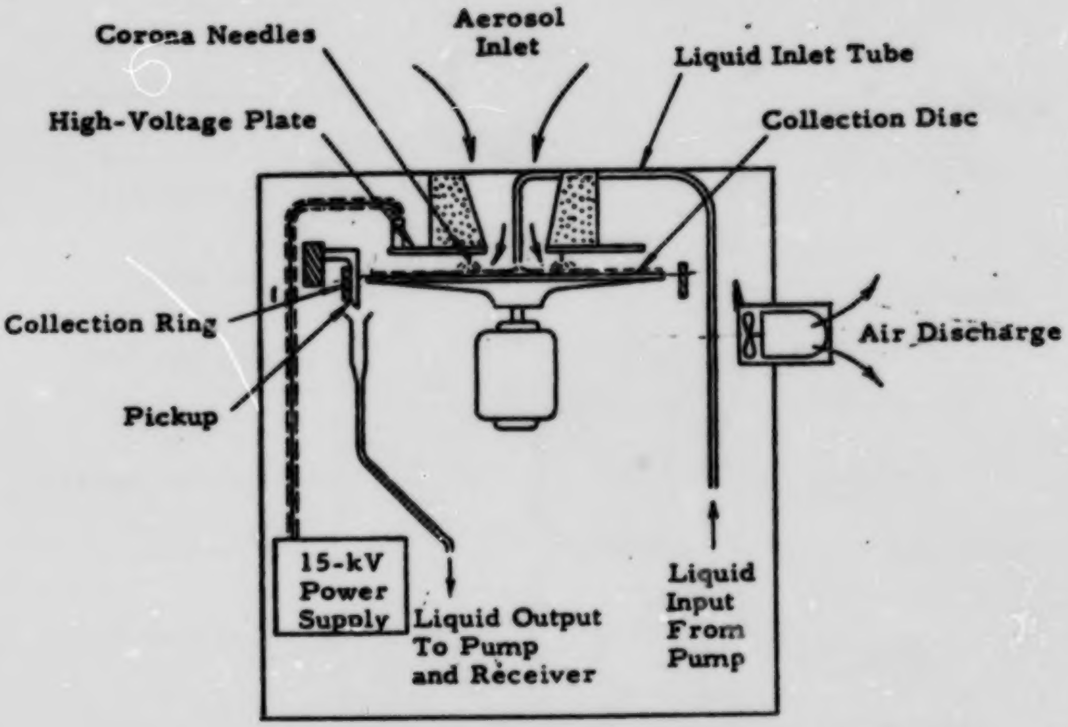
Corona Needles
Aerosol Inlet
Liquid Inlet Tube
High-Voltage Plate
Collection Disc
Collection Ring
Air Discharge
Pickup
15-kV Power Supply
Liquid Output To Pump and Receiver
Liquid Input From Pump

Figure D-2
SCHEMATIC DIAGRAM OF LITTON MODEL M LARGE-VOLUME AIR SAMPLER SYSTEM

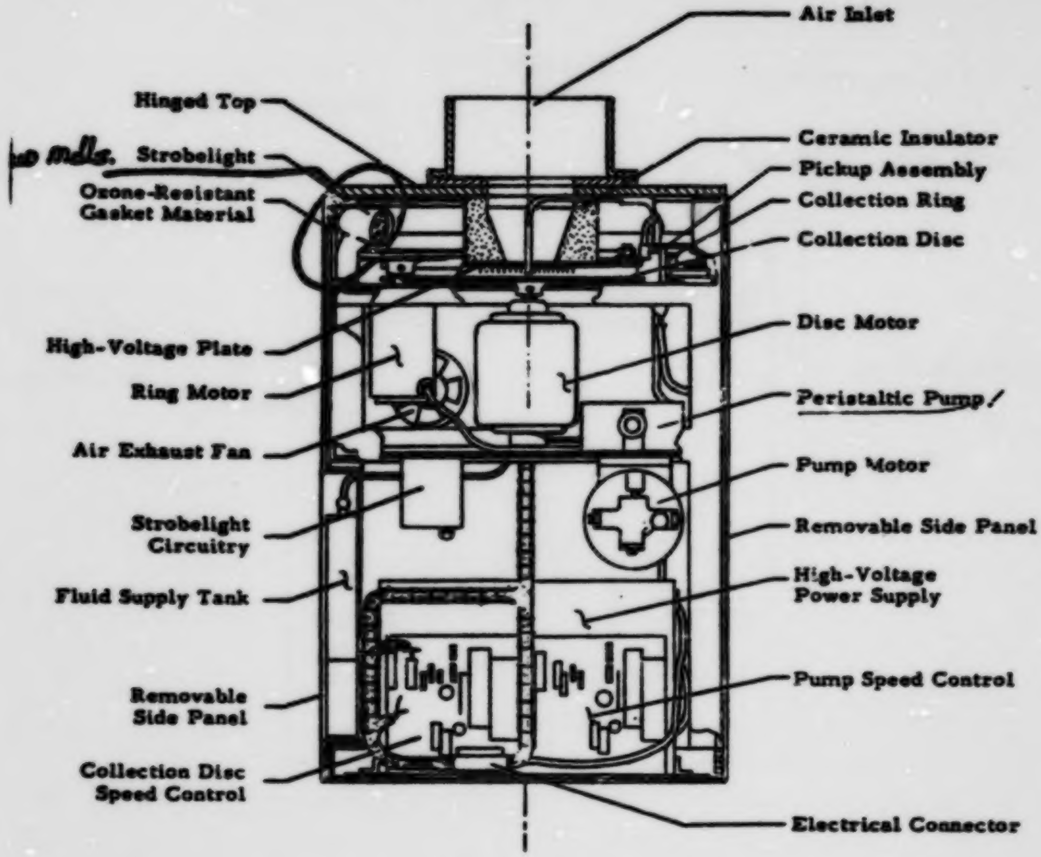
Air Inlet
Hinged Top
mdls.
Strobelight
Ozone-Resistant Gasket Material
Ceramic Insulator
Pickup Assembly
Collection Ring
Collection Disc
High-Voltage Plate
Disc Motor
Ring Motor
Peristaltic Pump /
Air Exhaust Fan
Pump Motor
Strobelight Circuitry
Removable Side Panel
Fluid Supply Tank
High-Voltage Power Supply
Pump Speed Control
Removable Side Panel
Collection Disc Speed Control
Electrical Connector

Figure D-3
INTERIOR VIEW OF LITTON MODEL M LARGE-VOLUME AIR SAMPLER

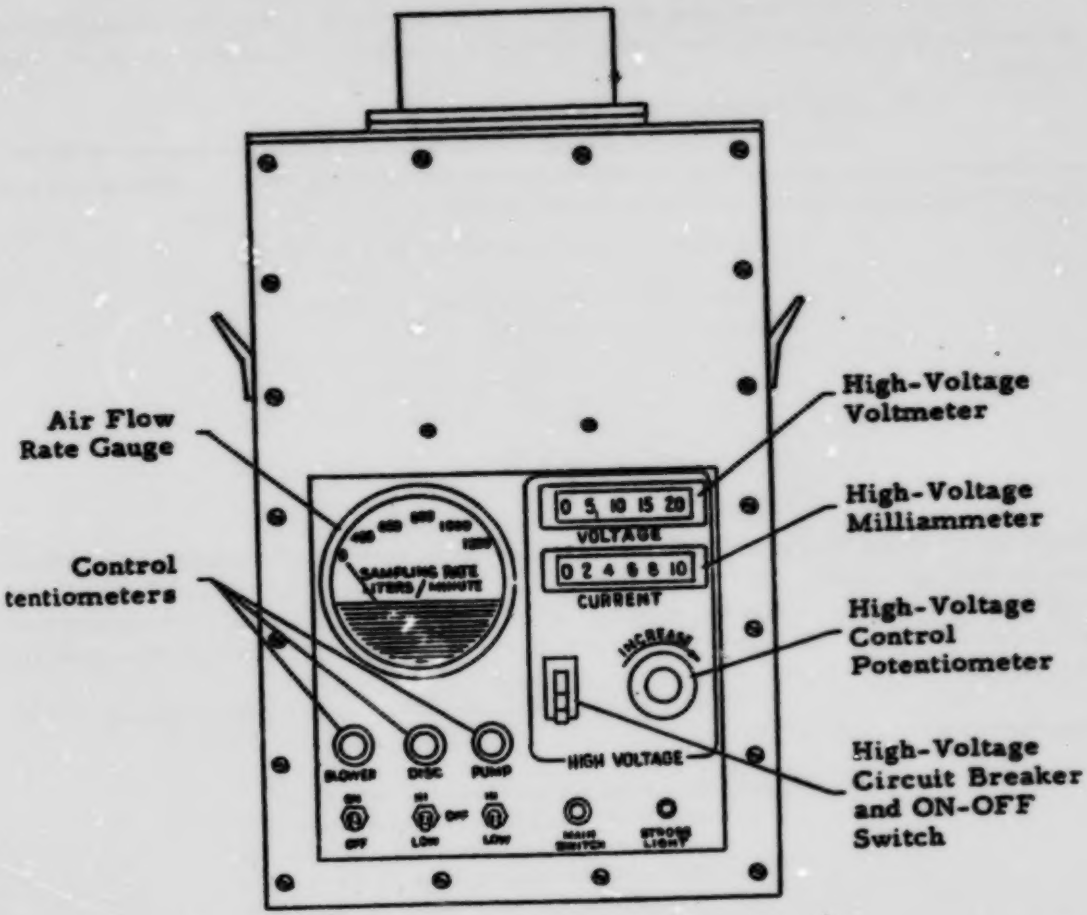
Air Flow Rate Gauge
Control tentiometers
High-Voltage Voltmeter
High-Voltage Milliammeter
High-Voltage Control Potentiometer
High-Voltage Circuit Breaker and ON-OFF Switch
400
600
800
1000
1200
SAMPLING RATE LITERS / MINUTE
0 5 10 15 20
VOLTAGE
0 2 4 6 8 10
CURRENT
INCREASE
HIGH VOLTAGE
BLOWER
DISC
PUMP
ON
OFF
HI
OFF
LOW
HI
LOW
MAIN SWITCH
STROBE LIGHT

Figure D-4
INSTRUMENT PANEL OF LITTON MODEL M LARGE-VOLUME AIR SAMPLER

and pump flow rate are controlled by high and low-range toggle switches, together with potentiometers. Although no direct readouts are provided for these two variables, calibrations are easily obtained so the arbitrary scales on the potentiometers can be converted to actual speed or flow rates. The high-voltage system is set with the aid of a potentiometer and is provided with the meter to show voltage and current."(83)

To facilitate visual observation of the surface condition of the disc in operation, the operator made observations through the windows with the aid of a flashlight. The air flow rate was set at 1000 liters/minute.

(2) *Liquid Collection Media*

A study was conducted to select the optimal transfer medium for shipment of the routine organism (coliphage) and the Pre-Fair selective organisms (*Klebsiella Pseudomonas,* Streptococcus and viruses). This study was intended to evaluate the stability of each organism in the following:

- Normal support medium (wastewater) for each organism (control).
- Brain-Heart Infusion Broth (BHI) with 0.1-percent Tween 80® (aerosol collection medium).
- BHI + 0.1-percent Tween 80® + 0.9-percent Difco Casamino acid + 0.1-percent Difco yeast extract.
- BHI + 0.1-percent Tween 80® + $0.5\mu g$/ml sodium thioglycollate.
- BHI + 0.1-percent Tween 80® + 2-percent fetal calf serum.
- Selected media depending on the organism (see results).

Each of the test media was inoculated with a known titer of each organism and was maintained at 4°C to simulate shipping conditions. Assays were conducted at 0, 24, 48, 72 and 120 hours after inoculation. The assay consisted of dulpicate analyses for poliovirus and bacteriophage in all media and times, and simple assays for other organisms. The organisms held at 4°C in their normal support media served as a control and were assayed in parallel with the test media.

Tables D-3 through D-7 present the results of this study. Clearly, at least two significant observations can be made from these data.

Observation 1. BHI + 0.1-percent Tween 80® (aerosol collection liquid) is an adequate support medium for all of the organisms evaluated. All other parameters being constant, there was no reason to substitute another medium for the transfer of samples from field site to lab for analysis. Although the poliovirus and f2 coliphage were relatively stable to 48 hours, bacterial concentrations were significantly reduced after 24 hours.

Observation 2. Significant reductions in organism concentrations were observed in wastewater in 24 hours. Thus, assay should be performed in less than 24 hours for all wastewater samples.

To indicate the consistency of the analyses in the various media, the replicate analyses of both poliovirus and bacteriophage were analyzed to determine the between-sample variability that occurs in these analyses. The precision of each determination is presented in terms of coefficients of variation.

Table D-8 presents the coefficients of variation for poliovirus calculations. The percent survival shown in Table E-2 is calculated on the basis of the relative amount present when compared to the

Table D-3

SURVIVAL OF POLIOVIRUS I (Chat) IN VARIOUS SUPPORT MEDIA AT 4°C

MEDIUM	% Survival at Time after Innoculation			
	24 hr	48 hr	72 hr	120 hr
Wastewater, Pond Effluent Pleasanton, California	74	56	32	46
BHI + 0.1% Tween 80®	122	105	66	82
BHI + 0.1% Tween 80® + 0.1% Difco Casamino Acid + 0.1% Difco Yeast Extract	105	74	64	77
BHI + 0.1% Tween 80® + 0.5 ug/ml Sodium Thioglycollate	94	74	57	74
BHI + 0.1% Tween 80® + 2% Fetal Calf Serum	110	94	74	82
Buffered Tryptose Phosphate + 0.1% Tween 80® + 0.5% Fetal Bonvine Serum	100	92	74	71
PBS (1X) in Glass	71	61	56	71

Table D-4

SURVIVAL OF F2 BACTERIOPHAGE IN VARIOUS SUPPORT MEDIA AT 4°C

MEDIUM	% Survival at Time after Innoculation			
	24 hr	48 hr	72 hr	120 hr
Wastewater, Pond Effluent Pleasanton, California	56	72	45	42
BHI + 0.1% Tween 80®	100	160	153	108
BHI + 0.1% Tween 80® + 0.1% Difco Casamino Acid + 0.1% Difco Yeast Extract	96	118	104	75
BHI + 0.1% Tween 80® + 0.5 ug/ml Sodium Thioglycollate	100	116	90	88
BHI + 0.1% Tween 80® + 2% Fetal Calf Serum	94	106	111	92
Buffered Tryptose Phosphate + 0.1% Tween 80® + 0.5 Fetal Bonvine Serum	100	132	106	91
PBS (1X) in Glass	91	93	74	56

Table D-5

SURVIVAL OF *KLEBSIELLA PNEUMONIAE* IN VARIOUS SUPPORT MEDIA AT 4°C

MEDIUM	% Survival at Time after Innoculation			
	24 hr	48 hr	72 hr	96 hr
BHI + 0.1% Tween 80®	102	73	47	58
BHI + 0.1% Tween 80® + 2% Fetal Calf Serum	88	49	30	16
BHI + 0.1% Tween 80® + 0.1% Difco Casamino Acid + 0.1% Difco Yeast Extract	65	51	52	39
BHI + 0.1% Tween 80® + 0.5 ug/ml Sodium Thioglycollate	65	43	43	25
GN Broth, Hajna	127	71	58	55
Buffered Glyceral Saline	50	67	71	56

Table D-6

SURVIVAL OF *STREPTOCOCCUS FECALIS* IN VARIOUS SUPPORT MEDIA AT 4°C

MEDIUM	% Survival at Time after Innoculation			
	24 hr	48 hr	72 hr	96 hr
BHI + 0.1% Tween 80®	177	74	87	78
BHI + 0.1% Tween 80® + 0.1% DIFCO Casamino Acid + 0.1% DIFCO Yeast Extract	137	54	72	63
BHI + 0.1% Tween 80® + 0.5 ug/ml Sodium Thioglycollate	119	60	44	67
BHI + 0.1% Tween 80® + 2% Fetal Calf Serum	139	62	72	71
Buffered Glycerol Saline	140	66	70	57

Table D-7

SURVIVAL OF *PSEUDOMONAS AERUGINOSA* VARIOUS SUPPORT MEDIA AT 4°C

MEDIUM	% Survival at Time after Innoculation			
	24 hr	48 hr	72 hr	120 hr
BHI + 0.1% Tween 80®	141	74	54	61
BHI + 0.1% Tween 80®+ 0.1% Difco Casamino Acid + 0.1% Difco Yeast Extract	64	31	18	39
BHI + 0.1% Tween 80®+ 0.5 ug/ml Sodium Thioglycollate	52	31	29	22
BHI + 0.1% Tween 80®+ 2% Fetal Calf Serum	74	47	34	39
GN Broth, Hajna	70	58	63	52
Buffered Glyceral Saline	88	42	11	12

Table D-8

PERCENT COEFFICIENTS OF VARIATION FOR SURVIVAL DETERMINATIONS—POLIOVIRUS I

Medium	Time (hrs.)			
	24	48	72	96
Wastewater, Pond Effluent Pleasanton, California	15	0	6	0
BHI + 0.1% Tween 80®	18	4	0	18
BHI + 0.1% Tween 80®+ 0.1% Difco Casamino Acid + 0.1% Difco Yeast Extract	10	5	28	9
BHI + 0.1% Tween 80®+ 0.5 µg/ml Sodium Thioglycollate	11	5	22	5
BHI + 0.1% Tween 80®+ 2% Fetal Calf Serum	3	4	5	9
Buffered Tryptose Phosphate + 0.1% Tween 80®+ 0.5% Fetal Bovine Serum	4	16	15	10
PBS (1X) in Glass	30	12	13	0

Determinations at time zero: 10 replicates, 7% coefficient of variation.

average of the ten determinations at time zero. Although these were made in varying media, all were made at the same time and are considered equivalent. The coefficient of variation for these determinations is seven percent. The aerosol support medium used, BHI with 0.1-percent Tween 80®, compares favorably with the other possible media and with the variation at zero hours.

Table D-9 contains the coefficients of variation for the bacteriophage determinations. In the initial determinations for bacteriophage, the analyses in the various media were made at different times and may not be equivalent. The survival is calculated relative to the determinations in those specific media, and the coefficient of variation for each of these is presented. There were only single determinations at time zero for both the BHI + 0.1% Tween 80® and for BHI + 0.1% Tween 80® Fetal Calf Serum, so that no coefficient of variation could be calculated for these media.

The variation in bacteriophage survival for the actual aerosol support medium was fairly constant over time, ranging from 3- to 14-percent. By comparison, the initial determinations for the bacteriophage exhibited variability ranging from 8- to 40-percent in the various media, which indicates that the medium chosen provided good repeatability.

Table D-9
PERCENT COEFFICIENTS OF VARIATION FOR SURVIVAL DETERMINATIONS—F2 BACTERIOPHAGE

Medium	Time (hrs)				
	0*	24	48	72	120
Wastewater, Pond Effluent Pleasanton, California	10	7	3	44	9
BHI + 0.1% Tween 80®	-+	14	4	7	3
BHI + 0.1% Tween 80®+ 0.1% Difco Casamino Acid + 0.1% Difco Yeast Extract	14	32	0	13	15
BHI + 0.1% Tween 80®+ 0.5 µg/ml Sodium Thioglycollate	-+	20	23	5	8
BHI + 0.1% Tween 80®+ 2% Fetal Calf Serum	40	0	0	7	14
Buffered Tryptose Phosphate + 0.1% Tween 80®+ 0.5% Fetal Bovine Serum	8	3	16	5	12
PBS (1X) in Glass	16	3	0	7	0

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* Treated separately since analyzed at different times.

+ Single analysis only.

(3) *Evaluation of High-Volume Aerosol Samplers*

In cooperation with the personnel at Naval Biosciences Laboratory, Oakland, California, Southwest Research Institute initiated a study to determine the sampling variability among the eight high-volume aerosol samplers available for this study. The study was divided into two major objectives. First, each individual machine was checked for accuracy of the meters used for adjusting air flow and high voltage. Secondly, the relative collection efficiencies of the samplers was evaluated in a controlled environment by comparing collection efficiencies relative to All-Glass Impingers (AGI's). This provided necessary data from which field testing results could be adjusted to account for different efficiencies.

A 4-inch diameter, David Instrument (63383/137M) Pin Wheel anemometer, was placed on a wire support directly above the 4.75-inch diameter large-volume sampler air intake to measure air intake flow. A two-minute sample was taken at a control setting of 1000 liters per minute. Finally, a 30-inch long, 48-inch diameter plastic stack was placed over the intake port of the large-volume air sampler. High voltage was determined by a Triplett Model 1603 Type 1 VOM with a ground probe connected to the sampler rotating table ground strap and high voltage probe connected to high voltage plate. All high voltage measurements were made with the sampler's high voltage indicator adjusted to 10 K.V.

Collection fluid flow rate was determined by using a graduated cylinder to measure the amount of tap water pumped in a minute at an indicated setting of 10 ml per minute.

This study was conducted at the Naval Biosciences Laboratory's wind tunnel facility in Oakland, California, which provided a controlled environment for testing eight large-volume air samplers. Refer to Figure D-5 for the experimental design used in the wind tunnel.

A Weston thermometer (30-120°F), Abbeon Humidity Indicator and an anemostat 11393 hot-wire anemometer were located in the center of the tunnel 54 feet downwind of the atomizer and at a height of 22 inches.

Aerosol was produced by a Wells' type reflux atomizer operating at 20 psi with fluid losses of 0.16 g per minute. The atomizer was located on a small platform 62 feet upwind of the samplers and the outlet was 6 feet above the floor of the tunnel, 18 inches from the near wall.

A flavobacterium species, grown in a liquid medium, to an initial assay of 6.1×10^9 colony forming units (CFU/ml), was used as a tracer organism. The same flavobacterium sample was used through several runs before adding a fresh suspension.

The medium for collecting the flavobacterium in the all-glass impingers (AGI's) and high-volume air samplers (LVAS) was Gel-Phosphate solution with approximately one percent antifoam B. Each of the large-volume air samplers had 100 ml for collecting purposes, while 20 ml were used in each of the AGI's. AGI's were used in the testing procedure to measure the concentration of flavobacterium during the runs and to provide a basis to compare all high-volume air samplers for efficiency of collection. The sampling rate of the AGI's was 12.5 liters of air per minute.

Eight (8) LVAS from different origins were used in this particular study (Table D-10).

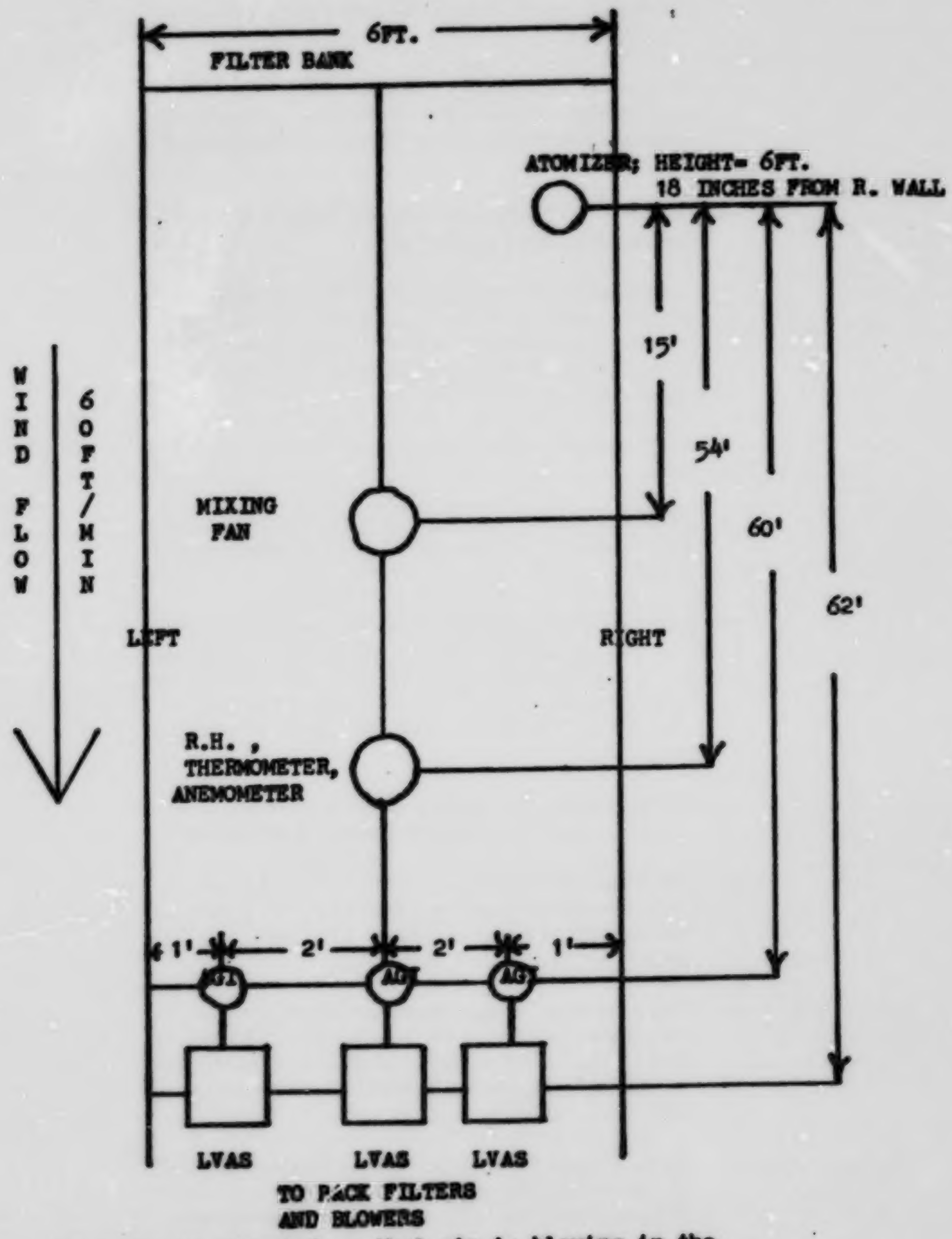
PROCEDURES FOLLOWED (Steps 1 through 20)

1. Place designated samplers in appropriate position in wind tunnel.

2. Decontaminate all LVAS prior to testing with the following:
   - Flush with 50 ml of 1% Clorox® solution.
   - Flush with 100 ml of sterile 1% sodium thiosulfate solution.
   - Flush with 100 ml of sterile distilled water.

Figure D-5

TYPICAL ARRANGEMENT OF APPARATUS IN THE WIND TUNNEL


6FT.
FILTER BANK
ATOMIZER; HEIGHT= 6FT.
18 INCHES FROM R. WALL
15'
54'
60'
62'
WIND FLOW
60 FT/MIN
MIXING FAN
LEFT
RIGHT
R.H. , THERMOMETER, ANEMOMETER
1'
2'
2'
1'
AGI
AGI
AGI
LVAS
LVAS
LVAS
TO PACK FILTERS AND BLOWERS

Note- Mixing fan is situated so that air is blowing in the vertical direction.

3. Adjust for proper setting for air flow and liquid flow.

4. Label each flask with appropriate run number and sampler number.

5. Recirculate the collecting media through the LVAS without the high voltage on until media starts to return to the original flask. Record the time for each machine that this step takes.

6. Adjust the high voltage to the proper setting and record the amount of time that this step takes.

7. Turn machine off with the master switch. All adjustments should be at the proper settings except for the high voltage on the sampler. Sampler H.V. level must be manually adjusted at the start of the run. Place the AGI's in the designated Places. Refer to Figure D-5.

8. Close tunnel doors and turn on proper blowers and mixing fan.

9. Place flavobacterium in the Well's atomizer in designated place and check that the atomizer is functioning properly. Refer to Figure D-5.

10. Operator in the wind tunnel tells the outside operator to start the run, at which time the outside operator will start the Well's Atomizer with 20 psi of air and close the forward door. When the inside operator starts the run, activate the stop watch to control the timing of sequential events.

11. Inside operator takes readings on the temperature, relative humidity and air flow. Refer to Figure D-5 as to position.

12. Inside operator removes covers for AGI's and LVAS. Operator checks that main power switch is in "OFF" position and turns on all master switches to LVAS and to the AGI vacuum pumps.

13. Inside operator, at the two-minute mark, turns on the main power switch that will start all the LVAS and the AGI's. If the LEAP sampler is being used, the inside operator manually adjusts the high voltage to the proper setting.

14. Inside operator checks to ensure the LVAS and the AGI's are functioning properly. Notations are made during the 10-minute run of any adjustments and/or observations.

15. Inside operator, at the 12-minute mark, turns off the main power switch which turns off all LVAS and AGI's simulta-

neously. Inside operator covers the intakes of the AGI's and LVAS. Outside operator turns off Well's Atomizer.

16. Inside operator takes second reading for temperature, relative humidity and air flow. During this period, the tunnel is being flushed for 10 additional minutes to remove any flavobacterium that might be aerosolized.

17. Inside operator notifies outside operator at the 22-minute mark to open rear tunnel doors.

18. Operators proceed to remove AGI's and return all media back to the original flasks with the LVAS high voltage in the "OFF" position. Record the time for media to return to original flasks for each machine.

19. Collect AGI's and media flasks and take to the laboratory for microbial assay.

20. Decontaminate all LVAS using the same procedures, as in Step 2.

The results obtained in the evaluation of large-volume samplers are presented in Tables D-10 through D-14.

In calibrating the efficiencies of the high-volume air samplers, normalizing the results of each sampler to the nearest AGI reduces the variability due to uneven distribution and concentrations of flavobacterium during the testing. Count of flavobacterium per liter of air normalized is calculated as the raw count per liter of air (Table D-13 divided by the nearest AGI (Table D-13) times 1000. Tables D-15 and D-16 show the normalized values for each sampler.

(4) Sampler Disinfection Procedure

The sampler is designed so the collection disc need not be removed for routine cleaning. To clean the disc and tubing, the following steps were taken:

DISINFECTION PROCEDURE

1. Fill a supply reservoir with distilled water.

2. Connect the appropriate tubing to the supply and effluent reservoir.

3. Remove the collection head assembly (aluminum inlet, plastic housing, ceramic nozzle and high voltage plate) by pulling upward on the plastic housing.

4. Turn the main switch to the "ON" position.

5. Remove the liquid input tubing from the collection head assembly and hold over the center of the rotating disc.

6. Adjust the pump speed control until the liquid flow rate is at least 10 ml per minute (2 ml/min for Model M).

Table D-10
LARGE-VOLUME AIR SAMPLERS

SwRI Assigned No.	Model	Serial Number	Origin
1	LEAP	1	SwRI
5	Litton M	219	NBL
6	Litton M	218	NBL
7	Litton M	201	NBL
8	Litton M	125	Dugway
9	Litton M	118	Dugway
10	Litton M	114	Dugway
11	Litton M	229	Dugway

Table D-11
CALIBRATION OF LVAS

			Air Intake (1/m) at 1,000 1/m Setting				
No.	Model	S.N.	Plastic Bag	Pin Wheel	Hot-Wire	Fluid Flow Rate at 10ml/min Setting	HV at 10 kv Setting
1	LEAP	3440		1,131		10.7[1]	11.5[2]
5	M	219		1,280	1,224		
6	M	218	1,182	1,128	1,078		10[3]
7	M	201		1,296		10.7[4]	10
8	M	125		1,089	912		11
9	M	118		1,113	981		10.5
10	M	114		1,214	1,002		11
11	M	229		1,131			10

---

[1] 16.2 at 16 indicated, 7.1 at 5 indicated.
[2] 9 at 8 indicated, 14 at 12, 16 at 14.
[3] 8 at 8 kv indicated, 12 at 12, 14 at 14.
[4] 3.52 at 5 indicated.

Table D-12
SAMPLER ARRAY IN WIND TUNNEL

Run Number	Samplers			
1	11	7	10	
2	9	7	10	
3	9	7	11	
4	9	7	11	
5	6	8	5	7
6	6	8	5	7
7	7	1	10	
8	7	1	10	
9	7	1	5	
10	7	1	5	
11	7	1	5	
12	7	1	5	

Table D-13
FLAVOBACTERIUM COUNTS IN LVAS AND ALL-GLASS IMPINGERS

(Counts per liter of Air[1])

Run No.	Samplers								All-Glass Impingers		
	1	5	6	7	8	9	10	11	L.	C.	R.
1				318			8[2]	1003	932		757
2				379		802	14[2]		1203		1102
3				453		590		168	1440		1613
4				470		418		365	1245		1284
5		676	819	489	331				997		1170
6		291	327	334	268				1045		1145
7	252			334			514		954	703	739
8	65			119			140		264	224	305
10	110	289		234					415	333	223

---

1. All large-volume air samplers (LVAS).
2. High voltage did not function properly.

Air Flow = 1,000 liters/min indicated.
Liquid Flow = 12ml/min.
High Voltage = 14 kv indicated.

Table D-14
HIGH VOLTAGE VARIATION RUNS

(Counts per liter of Air*)

Run No.	High Voltage Setting	Samplers 1	Samplers 5	Samplers 7	All-Glass Impingers L	All-Glass Impingers C	All-Glass Impingers R
9	8 KV	31.5	78	17	598	415	435
11	12 KV	179	473	228	680	489	659
12	10 KV	223	219	605	753	620	748

* NOTE: All large-volume air samplers (LVAS).

Air Flow = 1,000 liters/min, indicated
Liquid Flow = 12ml/min.

Table D-15
NORMALIZED COUNTS PER LITER OF AIR

Run	SAMPLER 1	SAMPLER 5	SAMPLER 6	SAMPLER 7	SAMPLER 8	SAMPLER 9	SAMPLER 10	SAMPLER 11
1				377			(11)	1076
2				328		667	(13)	
3				297		410		104
4				392		336		284
5		578	821	418	332			
6		254	313	291	256			
7	358			350			696	
8	290			451			459	
10	330	1296		564				
Avg.	326	709	567	385	294	471	577*	488

* Runs 1 and 2 discarded due to machine malfunction.

Table D-16
NORMALIZED COUNTS PER LITER AS FUNCTION OF THE HIGH VOLTAGE

Run	Voltage	SAMPLER 1	SAMPLER 5	SAMPLER 7
9	8 kv	70	142	22
12	10 kv	360	293	80
11	12 kv	366	718	335
Average (Table D-15)	14 kv	326	709	385

Footnote for Tables D-15 and D-16: Moving the decimal place one to the left gives the percent collecting efficiency as compared with the AGI. Example, sample 1 shows a 32.6% collection efficiency relative to the AGI.

7. With distilled water flowing onto the disc, sprinkle a laboratory detergent (for example, Alconox) onto the disc surface.

8. Using sandpaper (180 Three-M-ite works best) scrub the surface of the disc as it rotates. (For Model M, use sterile Kimwipe instead of sandpaper).

9. Clean the disc with the detergent solution by holding a clean tissue on the disc surface while the disc is rotating.

10. Observe the nature of the liquid film, and if it is not a thin continuous film, repeat the cleaning process.

11. Remove the detergent solution from the liquid collection system by allowing the sampler to operate for several minutes.

12. Replace the collection head assembly and connect the liquid input tubing.

For routine biological sampling, flushing the system with sterile liquid for at least five minutes was usually satisfactory. If more thorough sterilization was required, the following procedure was used:

1. Fill three supply reservoirs with:
    - a 1% solution of Clorox®
    - a 1% solution sodium thiosulfate
    - sterile distilled water.

2. Connect the reservoir containing the Clorox® solution to the pump.

3. Allow the Clorox® solution to flow through the sampler for 15 minutes.

4. IMMEDIATELY connect the reservoir containing the solution of sodium thiosulfate to the pump.

5. Flush the system for 15 minutes with the sodium thiosulfate solution.

6. Connect the reservoir containing the distilled water to the pump and flush the system for a period of 20 minutes.

(5) Sample Handling

Aerosol samples collected in the spray fields were immediately placed in a mailer containing two Kool-Pacs® at the completion of the aerosol run. The samples were next taken to the on-site laboratory and a 25-ml aliquot was aseptically taken from each individual sample. The two 4-ounce containers for each run were then properly labelled and maintained at 4°C until shipment for the following morning. The 25-ml aliquots were placed in a mailer with Kool-Pacs® and hand delivered to PEL for analysis of total coliforms, fecal coliforms and standard bacterial plate count. The 75-ml samples remaining were also placed in a mailer with Kool-Pacs® and air freighted non-stop to San Antonio where they were picked up by UTSA personnel. These samples were analyzed for specific bacteria and viruses. Careful attention was given to all samples so that they would remain at 4°C during transit.

A study was conducted to evaluate sample temperature stability during transport. A shipping container with one or two Kool-Pacs® was loaded with a variety of sample bottles simulating the normal practice for shipment. Tap water was the test medium. The water samples were either brought to 4°C or held at room temperature (approximately to 25°C) prior to packing. After loading the shipping containers in a selected Kool-Pac® and sample bottle configuration, the temperature change was monitored.

Figure D-6 is an illustration of the insulated shipping containers used throughout the field study. Figures D-7 through D-12 show the various Kool-Pac® and sample bottle test configurations used in the temperature study.

In the cases where two Kool-Pacs® were used and initial water temperature was 4°C, sample temperature dropped to 0°C within 2.5 hours and ice crystals formed. Under conditions of 4°C initial temperature and one Kool-Pac® , sample temperatures went to 2-3°C within 3 hours and remained at 5°C for more than 12 hours, the maximum shipping time required between the field site and the laboratory. For initial sample temperatures of approximately 25°C, a minimum temperature of 13°C was achieved after 7.0 hours. Consequently, all samples were immersed in ice or refrigerated at the site and brought to 4°C prior to packing for shipment. Only one Kool-Pac® was used and all samples (with three exceptions) arrived at the laboratory at 4°C ± 2°C.

Additional tests were conducted to determine optimal Kool-Pac® freezing time. Kool-Pacs® were placed in a conventional refrigerator/ freezer compartment for 6, 12, 18 and 24 hours, and then placed in a shipping container which held six liters of tap water at 4°C. From the results of these tests, it was determined that the optimal Kool-Pac® freezing time was between 12 and 24 hours. Results also reflect differences in individual Kool-Pacs® . Thus, a minimum freezing time of 18 hours was instituted for field operations.

b. All Glass Impinger (AGI) Samplers for Dye Aerosols

(1) Description of AGI Samplers (Calibration)

Dye samples were collected using 50 ml graduated all-glass impingers manufactured by Scientific Glass and Instruments, Inc. of Houston, Texas. A schematic of the collection system is as follows:

Rotameter 0-2 cfm	AGI	TRAP	Critical Orifice	Pump

The rotameter was used only for calibrating the system in the laboratory. Spot checks of the before-run and after-run flow rates were periodically conducted in the field to ensure proper flow rates were being maintained. The systems were calibrated weekly to be sure that no problems had incurred during field usage.

(2) Method of Dye Injection

For the purpose of estimating percent aerosolization of wastewater being sprayed, a 20-percent solution of Rhodamine WT dye was injected at a constant rate into the main pipeline supplying the fields' sprayers. The dye was injected into the main pressurized line approximately 180 feet upstream from the spray line using a Zenith gear pump calibrated to deliver a constant flow of dye solution. Dye was pumped into the line at a rate of approximately 300 ml/min. During the last two Pre-Fair aerosol runs, the Zenith pump malfunctioned and delivered at approximately 20 percent of the 300 ml/min rate. For the Post-Fair dye runs, a new larger capacity Zenith pump was used with no dye injection problems encountered.

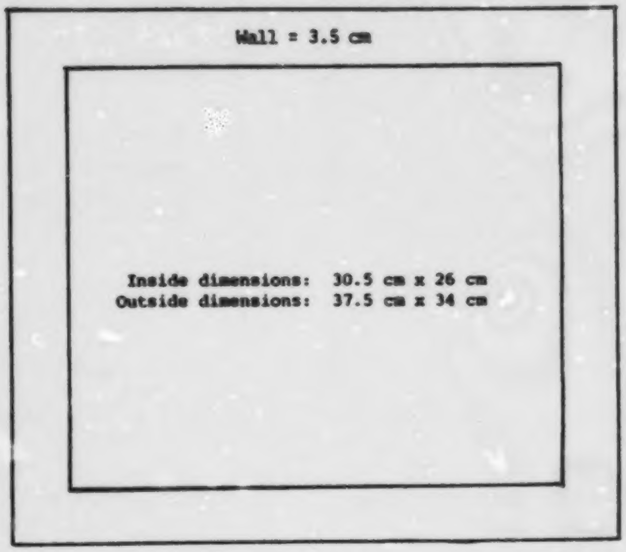

Wall = 3.5 cm
Inside dimensions: 30.5 cm x 26 cm
Outside dimensions: 37.5 cm x 34 cm

Figure D-6
SHIPPING CONTAINER INFORMATION

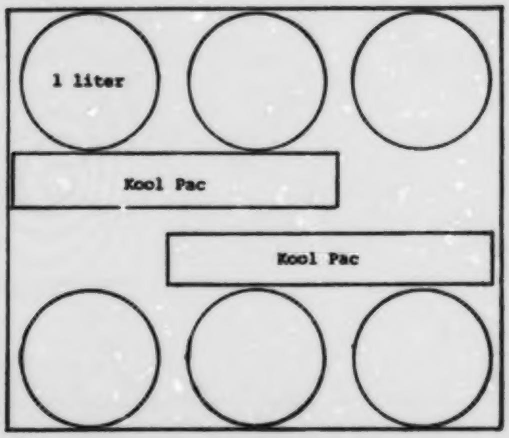

1 liter
Kool Pac
Kool Pac

Figure D-7
LARGE-VOLUME (six 1-liter samples).
TWO KOOL PACS®

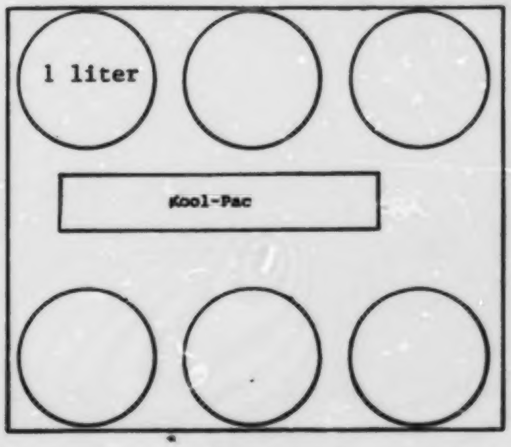

1 liter
Kool-Pac

Figure D-8
LARGE-VOLUME (six 1-liter samples)
ONE KOOL PAC®

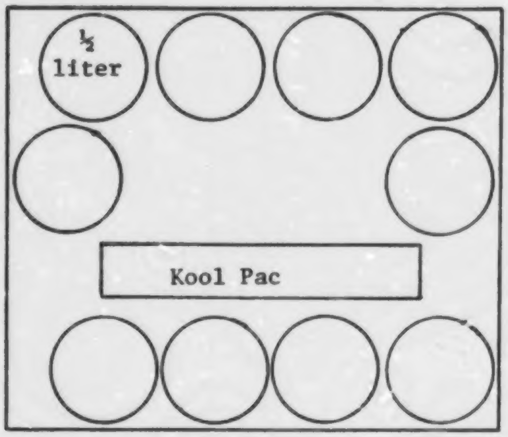

½
liter
Kool Pac

Figure D-9
QUALITY ASSURANCE (ten 1/2-liter bottles)
ONE KOOL PAC ®

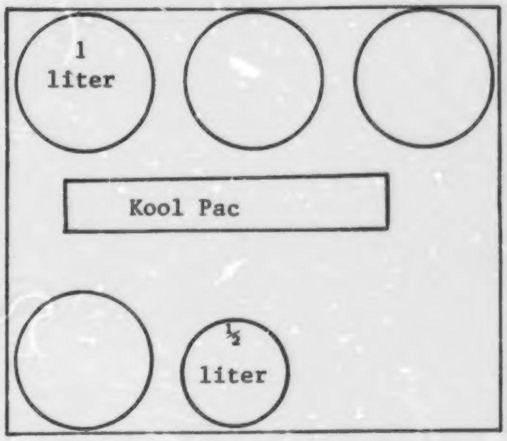

1
liter
Kool Pac
½
liter

Figure D-10
DAILY COMPOSITE (four 1-liter and one 1/2-liter samples) ONE KOOL PAC ®

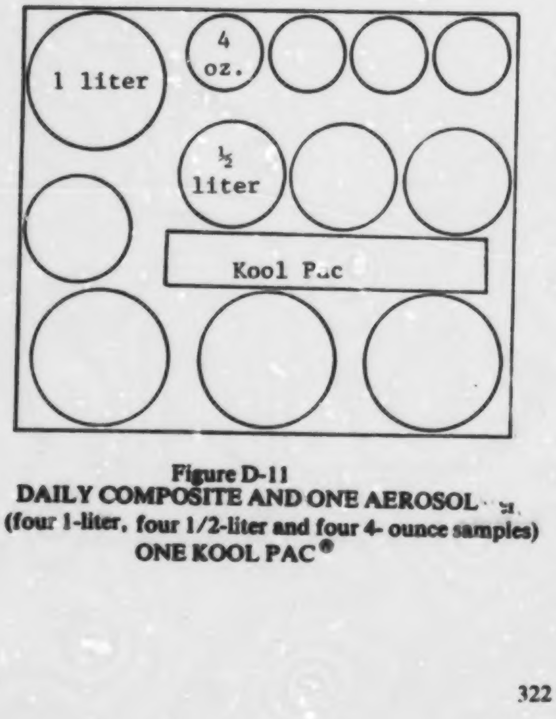

1 liter
4
oz.
½
liter
Kool Pac

Figure D-11
DAILY COMPOSITE AND ONE AEROSOL [illegible]
(four 1-liter, four 1/2-liter and four 4- ounce samples)
ONE KOOL PAC ®

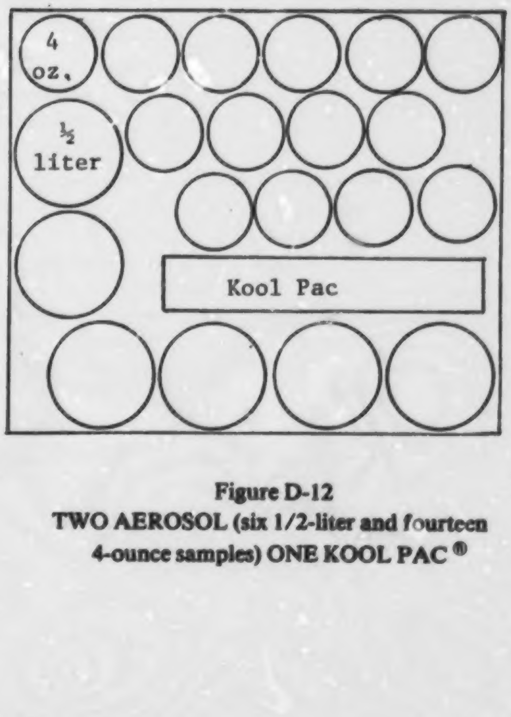

4
oz.
½
liter
Kool Pac

Figure D-12
TWO AEROSOL (six 1/2-liter and fourteen 4-ounce samples) ONE KOOL PAC ®

(3) Equilibrium Study

In order to determine the length of time required for the dye concentration in the spray to reach equilibrium, a test was conducted where grab samples were taken at the end of the spray line every minute for 20 minutes after the start of dye injection. The dye was injected at a constant rate for 15 minutes during this test. The results as shown in Table D-17 indicated that equilibrium was reached approximately five minutes after the start of dye injection and remained fairly constant throughout the time of dye injection and began to fall off approximately five minutes after the dye injection was stopped.

At the beginning and end of the first aerosol dye run, grab samples for dye analysis were taken at both ends and the middle of the spray line to determine how uniform the concentration of dye was in the spray line. The following results from this test indicated that the dye concentration was fairly uniform through the spray line.

	Dye Concentration (ppb)	
Sample Station	**Start**	**End**
East End	92,000	93,000
Middle	93,000	89,000
West End	94,000	89,000

Table D-17
DYE CONCENTRATION AS A FUNCTION OF TIME

Time (minutes)	Dye Concentration (ppb)	Time (minutes)	Dye Concentration (ppb)
1	118	11	20,483
2	98	12	20,069
3	95	13	19,655
4	95	14	19,862
5	291	15	20,689
6	20,069	16	21,517
7	19,862	17	21,103
8	20,689	18	20,689
9	20,276	19	21,103
10	20,689	20	15,931

(4) Aerosol Dye Sampling

When dye aerosol runs were conducted, 100 ml of deionized water were placed in the impinger and connected to the system described above. These systems were run at a rate of 1 cfm for a 30-minute period with sampling commencing at five minutes after the injected dye was sighted at the end sprinklers. At the conclusion of the run, the impinger liquid was transferred to a clean glass bottle, tightly capped and analyzed as soon as possible in the mobile laboratory. Grab samples were taken in glass bottles at both the beginning and the end of each run at an end sprinkler of the spray line.

Analysis of both the impinger liquid and grab samples was conducted the day of collection using the Turner Fluorometer Model 430 located in the mobile laboratory. Calibration of the instrument was performed using 0, 12, 24, and 48 ppb Rhodamine WT standards. It was determined that maximum response of the fluorometer to Rhodamine occurred with the following instrument conditions:

Excitation wavelength: 531 nm
Emission wavelength: 576 nm
Damp: 1
Blank: Low
Sensitivity: High
Slit: 15 nm

Impinger samples were analyzed without dilution whereas a 1:1000 dilution of the grab samples was performed prior to analysis.

c. *Rotorod Samplers for Fluorescent Particle (FP) Tracer*

Fluorescent particles (FP) were used as a quasi-quantitative tracer to document wind (and, consequently, aerosol plume) directions during the Post-Fair aerosol sampling. The FP tracer was collected on rotorod samplers, available from Metronics Inc., which were deployed generally downwind from the tracer release location. The deployment plans were based on an understanding of the terrain and physical features surrounding the fields and other limitations such as the number of available samplers and the time required to deploy samplers and analyze data. Sampling plans and procedures were sometimes modified to fit the actual field conditions.

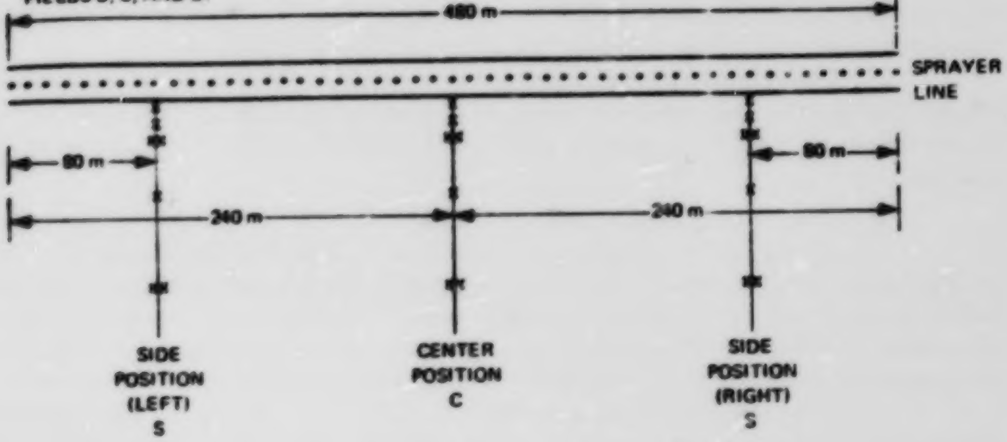
In general, the rotorod samplers were divided about equally between two sampler lines. The line nearest the FP source was about 200 to 300 meters downwind from the source with a sampler spacing of 50 meters. The other line of samplers was about 200 to 500 meters from the first line or about the same distance as the most distant aerosol samplers. The samplers in the second line were spaced at 100-meter intervals. The samplers were centered on the point on the line that was expected to be downwind of the FP source during the run.

An array of possible sampler locations were laid out and marked in advance of the aerosol sampling program. Figure D-13 depicts the locations that were used during the Pre-Fair study.

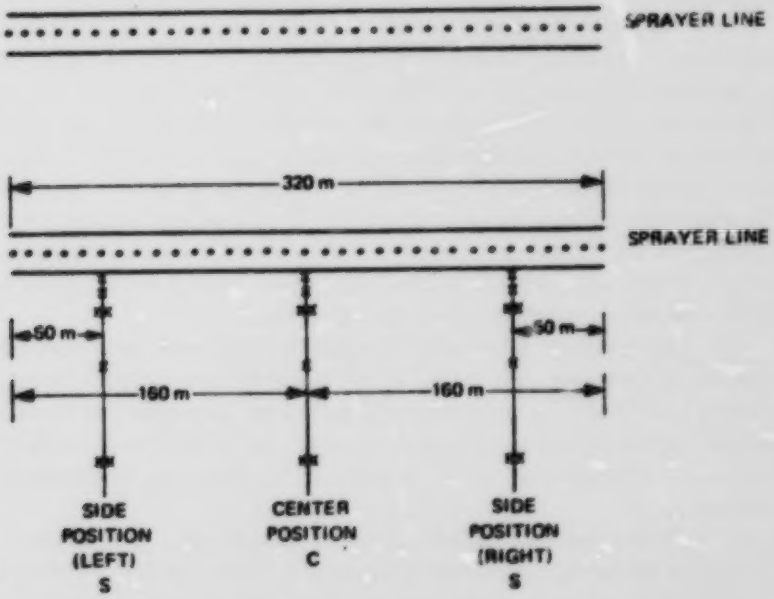
Rotorods were placed on the appropriate rotorod stakes just prior to each aerosol run and were collected immediately after the run was completed. The rotorods were transported to and from the on-site laboratory in boxes specifically designed for their transport. These boxes were decontaminated before use so that no (FP) contamination would occur. Special care was also taken in placing and collecting the rotorods so that contamination or sample loss would not occur. All rotorod samples were anlayzed at the conclusion of the aerosol runs to determine if the run met the design criteria for an acceptable run.

Figure D-13
POTENTIAL SAMPLER LINE POSITIONS IN PRE-FAIR SAMPLING

FIELDS B, C, AND D.


480 m
SPRAYER LINE
80 m
80 m
240 m
240 m
SIDE POSITION (LEFT) S
CENTER POSITION C
SIDE POSITION (RIGHT) S

FIELDS 0, 1, 2, 3, AND 4:


SPRAYER LINE
320 m
SPRAYER LINE
50 m
50 m
160 m
160 m
SIDE POSITION (LEFT) S
CENTER POSITION C
SIDE POSITION (RIGHT) S

B. Analytical Methods

1. Chemical Analysis of Wastewater Samples

a. Methods

During the Pre-Fair study all 48 daily composite wastewater samples were analyzed by the laboratory and method indicated in Table V.B-1 for "routine" chemical parameters. Twenty-five of the 48 composites were analyzed for the "selective" parameters by the indicated methods.

Since the daily effluent composite was discontinued during Post-Fair, routine analyses were conducted on the wastewater composite samples collected during aerosol runs at the laboratory and by the method indicated in Table V.B-2. Selective analyses were conducted on three of the grabs by the referenced methods.

b. Total Organic Carbon Holding Time Study

During the Pre-Fair wastewater characterization study, Total Organic Carbon (TOC) analyses were conducted by both Environmental Quality Analysts (EQA) of San Francisco and SwRI laboratories in San Antonio. The instrument utilized by EQA for these analyses was a Beckman Model 915 retrofitted to the updated 915A. This instrument consisted of two furnaces, one for the determination of total carbon and the other for total inorganic carbon. TOC was calculated by taking the difference of these two values.

The analytical procedure used was one recommended by Beckman which suggested 30 µl injections in both channels (total and inorganic carbon). Since the instrument channels had to be warmed up daily, injections were made first on the inorganic channel which obtained operating temperature before the total carbon channel. The inorganic channel was standardized by injecting 30 µl of sodium bicarbonate standard five times. The effluent sample was then injected an equal number of times utilizing the same sample size. As soon as the total carbon channel achieved operating temperature, it was standardized utilizing a potassium acid phthalate solution. The effluent sample was then analyzed for total carbon and TOC was calculated by taking the difference of the total carbon and inorganic carbon values.

The carbon analyzer utilized by SwRI consisted of a Beckman Carbonaceous Analyzer, Model IR-315 with a modified furnace (vertical orientation instead of horizontal) and retrofitted solid state Beckman Model 865 Infrared, Analyzer. The combustion system was kept at a constant temperature of 950°C to preclude the need for a warm-up period before analysis. Standardization was performed by injecting 20 µl, five times each, of a blank (deionized water) and a 20-, 50- and 100-ppm potassium acid phthalate standard solution. Before injection, the acidified sample was homogenized in a tissue grinder and sparged with a small stream of nitrogen for five minutes to expel any CO_2. After checking to ensure that the pH of the sample was <2 with pH paper, five to seven 20 µl aliquots were injected for sample analysis. Since no inorganic carbon (bicarbonate, carbonate or hydroxyl ion) could exist at a pH of <2, the total carbon value obtained from these injections was considered to consist only of organic carbon.

On samples obtained after June 4, 1976, EQA consistently reported values of "less than 1" for the effluent. These results must be due to analytical error, most likely the loss of CO_2. Since the wastewater samples were acidified, CO_2 could very easily be lost between running on the inorganic and the total carbon channels. Carbon dioxide loss would also account for unsatisfactory recovery of the internal spike by EQA. Since the results reported by EQA appeared inconsistent, they were not used and those obtained by SwRI were substituted.

In order to justify a holding time of up to 14 days, an independent holding study was conducted by SwRI in the San Antonio laboratories to determine the stability of TOC in acidified water samples.

To perform this study a sample was prepared by spiking engine lab cooling pond water with urine to a TOC level of approximately 25 µg/l. Ten clean two-dram vials were filled with this prepared sample and two drops of concentrated H_2SO_4 were added to each vial.

The following procedure was utilized for this study:

1. *First Run.* Samples were homogenized in a glass tissue grinder and sparged with nitrogen for five minutes. The TOC level was determined within two hours of sample preparation from the average of five sample injections.

2. *Second and all subsequent runs.* Samples were sparged with nitrogen for five minutes to remove any CO_2 formed by the conversion of TOC by bacterial action. The TOC level was determined from an average of five sample injections. Between analyses, samples were stored at 4°C in the dark.

The results of the study are shown in Table V.B-3. From these it can be concluded that acidified TOC's are stable for a period of at least 66 days when stored at 4°C.

c. *Fluorescent Particles*

Rotorod FP analysis was performed using a microscope combined with an ultraviolet light source. Six standard rotorods were provided for comparison with the actual rotorod samples. The standards provided were categorized as follows:

- Negative
- Very light
- Light
- Medium
- Heavy
- Very heavy

Results were tabulated on an analysis report form. (see next page)

2. Microbiological Assay

a. *Wastewater*

(1) *Routine Indicator Organisms*

Routine indicator organisms in the biological analysis of wastewater samples were total coliform, fecal coliform, standard bacterial plate count and coliphage. The methods employed for the coliforms and the standard bacterial plate counts are presented in Table V.B-4.

Coliphage samples were assayed using 18-hour *E. coli* K-13 as host organism which was shown to be the most sensitive bacterium tested (see Table D-18). Initially, samples were concentrated with the bentonite concentratfon procedure until it was determined that the coliphage levels were such that the concentration step was unnecessary.

Appropriate volumes (0.2, 0.3, or 0.5 ml) of the wastewater and 0.2 ml of host cells were added to 2.8 ml of liquified tryptose phosphate semi-solid agar (0.9 percent) and poured while warm (43°C) on 100-mm plastic petri dishes prepared with 20 ml of solidified tryptose phosphate agar (1.5-percent) base layer. When firm, the plates were inverted and incubated at 37°C for approximately eight to ten hours prior to counting. For each sample a minimum of ten plates were used.

(2) *Selective Organisms*

(a) *Viruses*

All samples were prepared for assay by the bentonite concentration method, which follows.

ROTOROD FP ANALYSIS REPORT

Date Mailed: ____________

to: David Camann, S.A. (copy)
R. Keith Kumbauld, Cramer (orig)

Aerosol Run Number ____________

Run Date ______________________

Field _____ Setting ______

Run Times __________ to _________

Side of Spray Line _________

Rotorod Sampler Data

	Stake Location	FP Level Code
Background		
Near Line		
Distant Line		

FP Level Key

Level Code	FP Level Interpretation
1	Negative
2	Very light
3	Light
4	Medium
5	Heavy
6	Very heavy

Comments:

____
FP Analyst

____
Field Supervisor

> To two liters of sample, 200 mg of bentonite clay and 20 ml of 1M $CaCl_2$ were added. The pH was adjusted to 6.0 with 1N HCl and the sample mixed with magnetic stir bars for 30 minutes. The suspended solids were collected and pelleted by light centrifugation. The supernatant was discarded, the solids resuspended in tryptose phosphate broth, eluted for five minutes and centrifuged again. The supernatant (approximately 10 ml) was decanted for assay. In the case of large-volume samples, four liters were concentrated.

Alternate virus concentration methodologies were evaluated as a component of the Phase I effort. These data show that the bentonite technique, as described herein, was one of the most efficient methods evaluated.

As a daily control, a known titer of Poliovirus Type I (Chat) was added to 0.5 liter of wastewater and concentrated. This procedure served to determine the concentration efficiency for that day's sample as well as cell sensitivity.

Table D-18
CHOICE OF HOST ORGANISM FOR COLIPHAGE ASSAY

Strain	As Is Assay Titer (pfu/liter)	Concentration Titer (pfu/liter)
K-13	6.2×10^4	6.8×10^4
C-600	5.8×10^4	2.2×10^4
B	5.1×10^3	5.0×10^3

Viruses were enumerated routinely on HeLa cell monolayers and reported as pfu/liter of original sample. Preliminary studies (see Table D-19) were performed to ascertain the efficiency of assay cells.

Table D-19
COMPARATIVE ISOLATION RATES, INDIGENOUS ENTERIC VIRUSES

Cell Line	No. Isolations/ No. Samples	% Positive
HeLa	5/8, 4/5	69
Baboon Kidney	1/6, 2/5	27
Buffalo Green Monkey	1/6	16.7

Assays were carried out using 0.2-ml samples on HeLa cell monolayers grown on 60-mm culture dishes in Eagle minimal essential medium plus 200 units of penicillin G per ml, 16.6 units of streptomycin per ml, 25 μg of Gentamicin® per ml and 0.5 μg of Fungizone® per ml.

Initially, two-thirds of the plates of each assay were incubated three days and scored for plaques; the remaining plates were incubated for five days and then scored. Incubation of all HeLa cell mono-layers was conducted at 37°C in a 5-percent carbon dioxide, humidified atmosphere. After incubation, the monolayers were stained with 2-percent neutral red in Hanks' balanced salt solution for two to three hours after which plaques were counted.

To avoid overgrowth of slower growing enteric viruses by poliovirus plaques, the technique was modified so that two-thirds of each sample was plated as before and stained after three days to visualize plaques. The remaining one-third of each sample was mixed with pooled anti-polio serum (types 1,2,3) diluted so that final antiserum concentration was 1:50. This level was shown experimentally to reduce stock virus titer by 95-percent or more. The virus concentrate-antipolio serum mixture was plated, incubated for five days and stained to visualize plaques. Results for five-day plaque counts reflect the sum of the three-day count and the poliovirus-suppressed five-day count.

A large, random number of plaques from the high-volume aerosol samples were selected for confirmation and subjected to indentification.

Field isolates were identified using the Lim Benyesh-Melnick enterovirus typing pools obtained through the National Institute of Allergy and Infectious Diseases (NIAID), National Institutes of Health, Bethesda, Maryland. A description of the preparation and use of these lyophilized pools has appeared in the Bulletin of the World Health Organization, 48:263-268, 1973 (Melnick, et al.).

The pools consist of 42 equine antisera combined into 8 pools, each pool containing 10-11 antisera. The pools have been designed in such a manner that a given antiserum appears either in one, two, or three pools. Thus, an unknown enterovirus may be identified by its neutralization by the pool or pools containing its homotypic antiserum.

The enterovirus pools identify polioviruses 1-3; CoxsackievirusA types 7, 9, and 16; Coxsackievirus B types 1, 2 and 4-6; and ECHO viruses 1-7, 9, 13-21, 24-27 and 29-33. If a field isolate is not neutralized by any of the A-H pools, special antisera pools for Coxsackievirus B-3 and ECHO viruses 11 and 12 also are supplied.

The lyophilized pools are rehydrated and diluted to contain, per 0.1 ml, 50 antibody units of each antiserum contained in the pool. The serum pools are heat inactivated at 56°C for for 30 minutes. The unknown field isolate, diluted to contain approximately $10^{3 \pm .5}$ TCID$_{50}$'s per 0.1 ml, is then added to each pool (A-H) and incubated at 37°C for 2 hours to allow specific neutralization. The same virus dilution used for neutralization is incubated in parallel and subsequently titrated to determine the actual TCID$_{50}$ of the virus employed in the test. Following incubation, two tissue culture tubes are inoculated with each serum-virus mixture. Homologous cell lines (in reference to the original isolation of the unknown enterovirus) are used. Inoculated tubes are incubated at 37°C for 7 days, with microscopic readings for cytopathic effect (CPE) beginning on day two. The results of neutralization are checked against the identification table provided.

(b) Bacterial Analyses

Analyses for fecal streptococci were performed in accordance with standard procedures and techniques that have been established for identification of these organisms in *Standard Methods*[84]. The "Multiple-Tube Technique" and the "Membrane Filter Technique" were employed during most of the study. Similar results were obtained from both procedures. However, only the data from the Membrane Filter Technique are reported since this procedure yielded more reproducible results.

Fluorescent pseudomonads (i.e. *Pseudomonas aeruginosa, Pseudomonas putida,* and *Pseudomonas fluorescens*) were determined by two quantitative procedures. The "Multiple-Tube Technique for *Pseudomonas aeruginosa*", described in the 13th edition of *Standard Methods*, was used. A positive presumptive test constituted the demonstration of greenish fluorescence under long-wave ultraviolet light rather than turbidity alone, a modification presented in the most current (14th) edition of *Standard Methods*[85]. Presumptive positive tubes were confirmed as described in *Standard Methods*[86]. Since fluorescent pseudomonads were present in large numbers in the large-volume, composite, and aerosol samples, a more direct and quantitative approach was found to be more useful than the most probable number analysis. Samples were diluted and plated in triplicate to previously solidified plates of King's medium B, commercially available as *Pseudomonas* Agar F (Difco), and to plates of Centrimide Agar (Difco). The former medium is optimal for production of fluorescent pigments (pyroverdin) by pseudomonads and the latter is a selective medium for *Pseudomonas*. Following incubation at 37°C for 48 hours, the number of fluorescent pseudomonads was easily determined, even on crowded plates, by noting the number of greenish fluorescent colonies with long-wave ultraviolet light in the dark. When the *Pseudomonas* F plates were excessively crowded with other types of organisms, all colonies from appropriate dilutions were picked from the selective *Pseudomonas* medium (Centrimide Agar) to sectors of *Pseudomonas* F agar plates. Following incubation the number of fluorescent colonies was determined as described above. In either case, positive colonies were confirmed by demonstrating that they were oxidase positive. The data presented for fluorescent pseudomonads are the results from the direct platings.

Originally, it seemed desirable to enumerate only *Pseudomonas aeruginosa* since it is the most frequently encountered non-fermenting Gram-negative rod in clinical specimens. *Pseudomonas aeruginosa* is the only *Pseudomonas* species known to excrete pyocyanin, a water-soluble, non-fluorescent blue pigment. King's Medium A, commercially available as *Pseudomonas* Agar P (Difco), is optimal for production of this pigment. It seemed that *Pseudomonas aeruginosa* might be determined by plating directly to this medium and noting the number of pigment-producing colonies. However, this was not possible since the medium is not selective for *Pseudomonas*. The mixed growth encountered on plating the various samples on this medium prevented the visual perception of the desired color change in the medium or the colonies. In contrast, fluorescent colonies were easily detected on *Pseudomonas* Agar F, even in heavily mixed cultures.

It should be noted that the incubation temperature of 37°C used for both the "Standard Methods Multiple Tube Technique" and the direct plating technique described here would selectively favor the enumeration of *Pseudomonas aeruginosa* compared to the other fluorescent pseudomonads which grow poorly at this temperature. Centrimide tolerance, the basis for the selective property of several media used for the isolation of *Pseudomonas*, including the selective medium used in this study, is a characteristic of all three fluorescent pseudomonads.

Spores of the anerobic *Clostridium perfringens* (*Cl. welchii*) are very resistant to disinfectants and other detrimental environmental effects and survive longer in water than conventional indicator organisms and most pathogens. This organism was determined by the test recommended by the World Health Organization. Aliquots of decimal dilutions of the test samples were inoculated in triplicate into freshly boiled litmus skim milk medium (with 0.1% "reduced" iron powder). The tubes were heated at 80°C for 15 minutes to destroy vegetative cells, incubated at 37°C and examined over a period of 5 days for positive "stormy fermentation" reactions. To decrease the incidence of false positive tubes, the tests were confirmed by examination of wet mounts and stained smears for nonmotile, encapsulated, Gram-positive rods. Spores, if present, were located centrally within the cells. Computation of the MPN-index was accomplished by consulting probability tables used for estimation of coliforms.

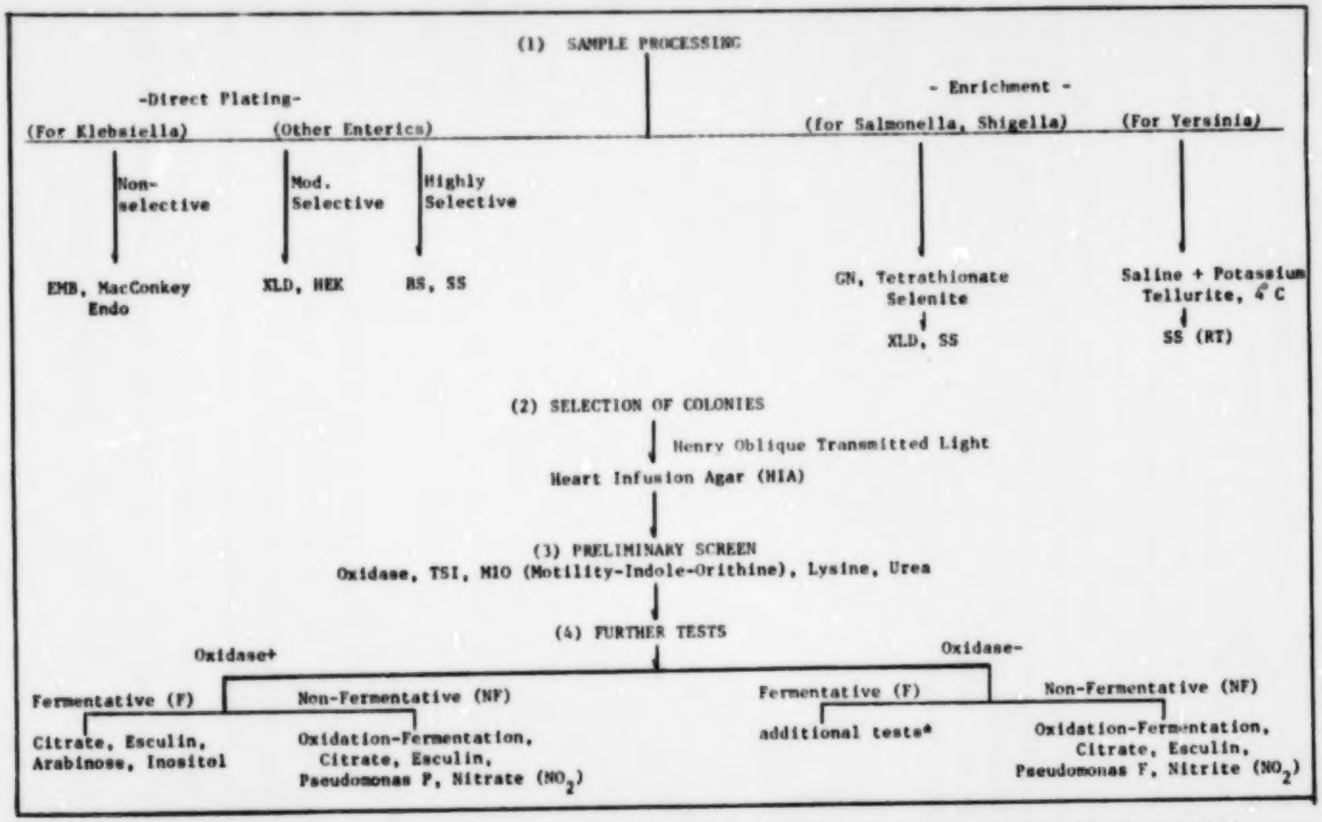
As emphasized in *Standard Methods*, differentiation of the genus *Klebsiella* from other coliform organisms is important because of its association with human respiratory and genitourinary infections. Although not uncommon in feces, sewage and even chlorinated municipal water supplies, the selection of *Klebsiella* as one of the four organisms in the routine selective bacteriological screen was a poor choice for the present study. Quantitation of *Klebsiella* in the highly mixed samples from the Pleasanton site was complicated by the lack of an isolation procedure that is highly differential or selective for these organisms. The capacity of *Klebsiella* and *Enterobacter* to fix nitrogen and thus to form large colonies on a nitrogen-deficient medium has been employed for the differential isolation of these organisms from feces. However, the more commonly employed ability of *Klebsiella* to produce large mucoid colonies on differential enteric media containing a high concentration of carbohydrate (e.g. EMB agar) was utilized in the present study.

The isolation and identification scheme employed for *Klebsiella* is summarized in Figure D-14. *Klebsiella ozaenae* and the rare *Klebsiella rhinoschleromatis* were screened for, in addition to the more common *Klebsiella pneumoniae*. A number of problems associated with quantitation of these organisms became obvious in the earliest parts of this study. Surprisingly, the majority of organisms picked from all of the "enteric" plating media employed were oxidase positive. These included organisms picked from moderately and highly selective enteric media. Furthermore, approximately one fourth of the mucoid colonies picked from nonselective enteric media (EMB, ENDO, MacConkey) were oxidase positive. In both cases, many of the oxidase positive organisms were fermentative and nonmotile in the semisolid MIO medium (but motile in wet mounts of broth cultures). This could lead to incorrect identifications of organisms as *Klebsiella* if the oxidase test is not employed as a standard procedure.

Most *Klebsiella* in nature are encapsulated and give rise to mucoid colonies, but rough forms also occur. Finally, the closely related genera *Enterobacter* and *Serratia*, that "classically" produce less mucoid colonies than *Klebsiella*, cannot be differentiated from the latter on the basis of colonial morphology alone.

The above considerations and the large number of mucoid colonies observed following plating of the samples to the nonselective enteric media, made it apparent that quantitation of *Klebsiella* would have to be carried out in an indirect manner. Approximately 700 individual mucoid colonies, randomly picked from composite and aerosol samples plated throughout this study to EMB, MacConkey and ENDO agars, were tested for identification as *Klebsiella*. From this analysis, EMB was selected as the medium of choice for determination of total mucoid colonies and a figure of 27.5% was obtained for the percentage of mucoid colonies from EMB that were *Klebsiella*. This figure, used for calculation of *Klebsiella* in composite and high-volume samples, was taken from the fact that 39/142 mucoid colonies picked from composite samples plated to EMB were biochemically identified as *Klebsiella*. Determination of a value for "calculated *Klebsiella*" in aerosol samples based on the number of mucoid colonies is more difficult and perhaps unjustified for a number of reasons. Many of the aerosol samples contained "abnormally" high numbers of orga-

Figure D-14
SCHEMATIC DIAGRAM OF ENTERICS ISOLATION


(1) SAMPLE PROCESSING
-Direct Plating-
(For Klebsiella)
(Other Enterics)
- Enrichment -
(for Salmonella, Shigella)
(For Yersinia)
Non-selective
Mod. Selective
Highly Selective
EMB, MacConkey Endo
XLD, HEK
BS, SS
GN, Tetrathionate Selenite
XLD, SS
Saline + Potassium Tellurite, 4° C
SS (RT)
(2) SELECTION OF COLONIES
Henry Oblique Transmitted Light
Heart Infusion Agar (HIA)
(3) PRELIMINARY SCREEN
Oxidase, TSI, MIO (Motility-Indole-Orithine), Lysine, Urea
(4) FURTHER TESTS
Oxidase+
Oxidase-
Fermentative (F)
Non-Fermentative (NF)
Citrate, Esculin, Arabinose, Inositol
Oxidation-Fermentation, Citrate, Esculin, Pseudomonas P, Nitrate (NO2)
Fermentative (F)
additional tests*
Non-Fermentative (NF)
Oxidation-Fermentation, Citrate, Esculin, Pseudomonas F, Nitrite (NO2)

* Arabinose, adonitol, arginine dihydrolase, citrate, esculin, JTR (Jordans tartrate), KCN, malonate, MR, VP, mannitol, dulcitol, rhamnose, salacin, sorbitol, motility (wet-mount and/or semisolid agar), indole from tryptone broth, enterotube, salmonella antisera, shigella antisera.

nisms that grew on the nonselective enteric media (EMB, ENDO, MacConkey). In some cases the total numbers were greater than total colony counts in companion composite samples. Aerosol samplers may not have been adequately decontaminated between runs and/or the samples may have been inadequately handled prior to shipment for analysis. A large number of the aerosol samples (39 of 146 samples examined) yielded large numbers of a pure culture or a mixture of two to three types when plated to the nonselective enteric media. When such samples were observed, the suspect organisms were subjected to biochemical identification. The predominant organism was often *E. coli* or a fluorescent pseudomonad. In eight separate runs, the same sampler yielded large numbers of a mucoid *Ser. liquefaciens*. If the 39 "contaminated" samples are ignored, a value of 1.9% was obtained for the percentage of mucoid colonies from EMB identified as *Klebsiella*. This was based on 3/155 mucoid colonies randomly picked from the remaining 62 samples plated on EMB. The significance of the tenfold difference in this value, compared with that obtained for composite samples is unexplained. It may be that other samples also contained "abnormally" high numbers of mucoid colonies, but not so many that the samples were put in the "pure culture" category. This would result in an inflated mucoid colony number. These results also might reflect a difference in the ability of *Klebsiella* to survive aerosolization as compared with other mucoid colony formers.

As a result, *Klebsiella* was not sought in the Post-Fair analyses and mycobacteria were substituted. Mycobacteria were assayed quantitatively by a procedure which almost totally suppresses sewage saprophytes while permitting recovery of most mycobacteria. The sample was treated for 20 minutes with 500 mg/l of Benzalkonium chloride (Zephiran), diluted and plated to the surface of previously prepared plates of Middlebrook 7H10 Agar. Plates were incubated with 5-percent CO_2 and examined over a period of one month for the appearance of colonies of mycobacteria. Colonies that appeared were identified by examination of stained (Ziehl-Neelsen) smears for acid-fast bacilli and by other procedures as outlined in Figure D-15.

c. Large-Volume Microbial Characterization of Effluent

The information obtained during Pre-Fair was intended to assist in examing the possible relationship between selective and routine microbiological assays and which may be utilized for comparison with other water quality (chemical) parameters. These samples (1-4 liters each) were taken at the inlet to the irrigation pumps early enough in the morning to ensure that the samples could be placed on the nonstop morning flight to San Antonio.

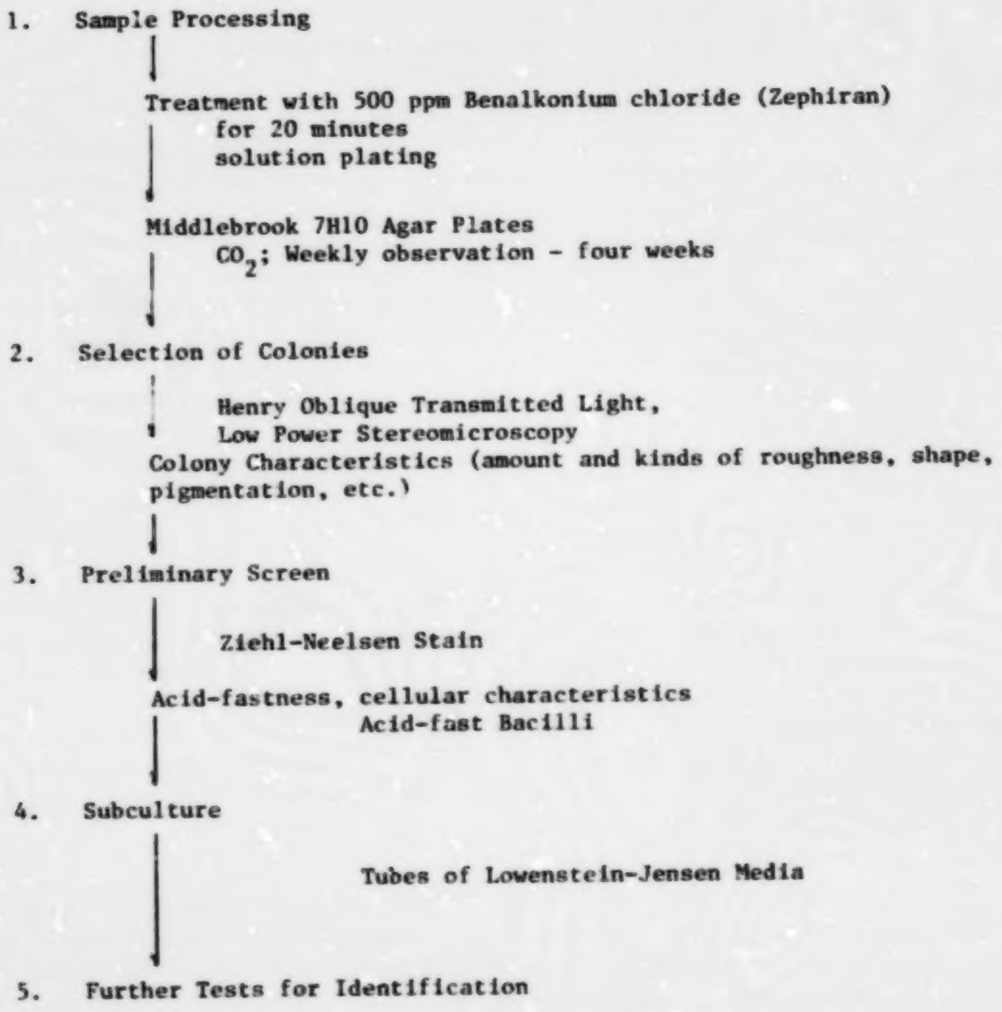
In addition to assays for *Klebsiella*, *Pseudomonas*, *Cl. perfringens* and fecal streptococci described previously, a screen for 16 selected microbial types was carried out. Many of the microorganisms listed are overt pathogens (*Salmonella, Shigella, Neisseria, etc.*), while others (*Serratia*, alcaligenes, etc.) have at times incorrectly been regarded as harmless. The latter are often opportunistic agents in infections. All of the organisms can be isolated from feces and should provide the necessary information for selective analyses on a regular basis of effluents and aerosols for pathogens and potential pathogens.

Summary of microbial types sought in the pathogen screen:

(1) *Staphylococcus aureus*
(2) Mycobacteria
(3) *Leptospira*
(4) *Shigella*

Figure D-15

SCHEMATIC DIAGRAM OF MYCOBACTERIA ISOLATION (Post-Fair)


1. Sample Processing
Treatment with 500 ppm Benalkonium chloride (Zephiran)
for 20 minutes
solution plating
Middlebrook 7H10 Agar Plates
CO_2; Weekly observation - four weeks
2. Selection of Colonies
Henry Oblique Transmitted Light,
Low Power Stereomicroscopy
Colony Characteristics (amount and kinds of roughness, shape, pigmentation, etc.)
3. Preliminary Screen
Ziehl-Neelsen Stain
Acid-fastness, cellular characteristics
Acid-fast Bacilli
4. Subculture
Tubes of Lowenstein-Jensen Media
5. Further Tests for Identification

(5) *Salmonella* (including Arizona)
(6) *Enterobacter*
(7) *Serratia*
(8) *Edwardsiella*
(9) *Escherichia*
(10) *Citrobacter*
(11) *Proteus*
(12) *Providencia*
(13) *Yersinia*
(14) *Neisseria* (pathogenic)
(15) Aeromonas and other Oxidase-Positive Fermenters
(16) Gram-Negative Nonfermenters

(1) *Staphylococcus aureus*

A number of investigators have reported that staphylococci have a greater resistance to residual chlorine than the coliforms and fecal streptococci. Staphylococci as an indicator of pollution in swimming pools may be primarily a measure of pollution arising from the bathers' eyes, ears, nose and throat. However, staphylococci also are a component of the normal gut flora of man and may provide a useful measure of fecal pollution, particularly in treated waters. In early parts of the study, a quantitative membrane filter (MF) procedure described in *Standard Methods* was employed. The sample size varied in order to yield MF counts within a desired 40-100 colony range on M-Staphylococcus Broth-soaked absorbent pads. However, enumeration of yellow pigmented colonies and their subsequent confirmation as *S. aereus* was complicated by the heavy mixed growth on the filters. This procedure was abandoned and samples (0.1 ml) were plated in triplicate directly to previously solidified plates of Mannitol Salt agar. This change resulted in a marked reduction of "background" growth, but reduced the volume of sample that could be analyzed. Typical colonies showing a yellow zone of mannitol fermentation were fished for confirmation of identity by staining techniques and coagulase production.

(2) *Mycobacteria*

Tubercle bacilli survive for long periods in feces, sewage and water and have a greater resistance to chlorination than the coliform indicator group. Mycobacteria were assayed quantitatively by a procedure which almost totally suppresses sewage saprophytes while permitting recovery of most mycobacteria. A large sample was treated for 20 minutes with 500 ppm of benzalkonium chloride (Zephiran), diluted and plated to the surface of previously prepared plates of Middlebrook 7H11 agar. Plates were incubated with 5-percent CO_2 and examined over a period of one month for the appearance of colonies of mycobacteria. Colonies that appeared were identified by examination of stained (Ziehl-Neelsen) smears for acid-fast bacilli and by other procedures as outlined in Figure D-16.

(3) *Leptospira*

Members of the genus *Leptospira* have been implicated in a variety of human diseases. Entry into the host generally occurs through abrasions of the skin or through mucosal surfaces following contact with water contaminated with urine of infected humans or wild and domesticated animals. Pathogenic leptospires may survive for months in neutral or slightly alkaline waters. "Saprophytic" or "water" leptospires (*L. biflexa*) are found predominately in fresh surface waters and are rarely associated with infection. The assay for leptospires was accomplished by their initial separation from contaminating microbes by passage of the test samples through 0.45 μ membrane filters. Leptospires will pass through the filters because of their small diameters. The filtrate and unfiltered samples were diluted into tubes of Stuart's liquid medium (with 10-percent inactivated serum) containing 200 μg/ml of 5-fluorouracil to inhibit the growth of contaminating microorganisms. The tubes were incubated in the dark at 28°C. Cultures were exam-

Figure D-16
SCHEMATIC DIAGRAM OF MYCOBACTERIA ISOLATION (Pre-Fair)

1. **Sample Processing**

↓

Treatment with 500 ppm Benzalkonium Chloride (Zephiran)

↓ for 20 minutes

Dilution Plating

Middlebrook 7H11 Agar Plates

↓ CO; Weekly Observation - four weeks

2. **Selection of Colonies**

↓ Henry Oblique Transmitted Light,
Low Power Stereomicroscopy

Colony Characteristics (amount and kinds of roughness, shape, pigmentation, etc.)

↓

3. **Preliminary Screen**

↓ Ziehl-Neelsen Stain

Acid-Fastness, Cellular Characteristics

↓ Acid-Fast Bacilli

4. **Subculture**

↓ Tubes of Middlebrook 7H11 Agar Enriched
with 0.25% L-Asparagine; CO_2

5. **Further Tests**

↓

Rate of growth
Pigmentation before and after exposure to light
Niacin
Arylsulfatase (3 day)
Catalase (room temperature)
Catalase (after 68 C heating)
Nitrate Reduction
Tween Hydrolysis
Urease

ined at 5-7 day intervals over a total period of 6 weeks for growth and microscopically (dark-ground microscopy) for the characteristic leptospiric morphology and motility.

(4) *Shigella*

A qualitative procedure for the concentration and isolation of *Shigella* was carried out as described in *Standard Methods*. Filtration through diatomaceous earth was used to concentrate a large proportion of all microorganisms present in a 1- to 2-liter sample. Large volumes of samples relatively free of turbidity also were passed through a single membrane filter. The resulting plug of diatomaceous earth was divided into equal portions for addition to bottles of GN broth (BBL). One-half of the same plug also was used for enrichment of *Salmonella* as described below.

A 10-ml portion of the unconcentrated sample was added to a separate bottle of enrichment medium. After 24 hours enrichment at 37°C, aliquots from the bottles were plated for isolated colonies onto xylose lysine desoxycholate (XLD) agar. Although several enrichment-plating media combinations are available for isolation of *Shigella*, the GN-XLD combination repeatedly has been observed to be superior for recovery of the organism.

Presumptive identification of *Shigella* and other *Enterbacteriaceae* (organisms 5-13) was accomplished by the procedures indicated in Figure D-14. These included colonial morphology, microscopic appearance of stained smears, and selected biochemical tests. A preliminary biochemical screen was achieved by application of a four-tube method including triple sugar iron agar (TSI), motility-indole-ornithine medium (MIO), Christensen's urea agar and lysine decarboxylase medium. The combination of eight separate tests obtained with these media permitted presumptive identification of most isolates of *Enterobacteriaceae*, and in some cases allowed specific identification. A different four-tube screen consisting of motility-indole-lysine medium, TSI, urea and bile esculin agar was used in the earliest parts of this study. This screen proved to be less satisfactory and was abandoned. Enterotubes (Roche Diagnostics), sterile multimedia tubes for identification of *Enterobacteriaceae*, were employed in some large-scale screening procedures. This system has been evaluated extensively and its current version coupled with Encise II (a large data base approached by a four-digit reference) yields results comparable to conventional multiple tube-single tests at a confidence level of approximately 97%. The benefits include convenience, a reduction in the time for performing the various tests and preparing media and a simplification of the reading and evaluation of the tests. The oxidase test was performed as a part of the routine screen on every isolate picked from the "enteric" media shown in Figure D-14. The procedure used was Kovac's method. The importance of this test for the proper identification of Gram-negative rods cannot be overemphasized.

The results obtained in the screening procedure served as a guide in the selection of additional tests (i.e. tests from the definitive treatise on *Enterobacteriaceae* by Edwards and Ewing necessary to permit the identity of all isolates to the species level. All *Salmonella* and *Shigella* isolates were confirmed by agglutination tests with specific antisera.

(5) *Salmonella* (including Arizona)

A quantitative MF procedure for *Salmonella typhi* is described in *Standard Methods*. Following filtration of measured volumes of sample (the volume filtrable depending on the level of organic and particulate matter), filters were incubated on pads containing M-bismuth sulfite broth for 18-20 hours at 35°C for a total of 30 hours, suspect colonies were picked and identified as described above.

Enrichment for *Salmonella* (including Arizona) was carried out following concentration of samples as described above. Portions of the diatomaceous earth plug and an unconcentrated 10-ml sample were enriched in separate bottles of selinite and tetra-thionate broths. After enrichment, aliquots were streaked for isolated colonies onto a moderately selective medium (XLD or Hektoen enteric agar) and a highly selective medium (SS). Identification of suspect colonies was accomplished as described above.

(6-13) *Other Enterobacteriaceae*

Members of the other genera of *Enterobacteriaceae* (i.e. numbers 6-13) were determined by picking colonies from samples dilution plated to moderately selective (XLD and Hektoen) and highly selective (Bismuth Sulfite and SS) enteric plating media. Two-to-three representatives of every colony type observed under low power microscopy with oblique transmitted lighting were subcultured for identification as illustrated in Figure D-14. All colony types picked for identification following enrichment for *Salmonella* and *Shigella* as described before also were characterized to the species level for inclusion in this aspect of the study. Colonies from the nonselective enteric plating media (EMB, ENDO and MacConkey) were not selected for this aspect of the study. Since the coliforms (particularly *E. coli*) constituted the major portion of *Enterobacteriaceae* on the nonselective media, their light-to-heavy supression on the selective media was desirable to increase the chance of picking other types.

Yersinia enterocholitica was determined by selective enrichment of membrane filter-concentrated samples or diluted samples refrigerated in isotonic saline with 25 g/ml of potassium tellurite and plated to SS agar. After incubation for two days at 25°C, colonies were identified as described previously.

(14) *Pathogenic Neisseria*

The two pathogenic species of neisseria (*Neisseria meningitidis* and *Neisseria gonorrhea*) are limited to humans as natural hosts. Both organisms survive poorly outside of the body and their isolation is unlikely. However, both can be isolated from feces, and in females with gonorrhea, the rectum is infected in approximately one-half of the cases (in 5-10 percent of the cases it may be the only site infected). Dilutions of the samples were plated to Thaeyer-Martin agar with trimethoprim lactate (5 mg/liter). Addition of the latter increases the selectivity of TM when used for examination of rectal specimens. Oxidase positive colonies were examined microscopically for typical Gram-negative diplococci. The procedure does not distinguish pathogenic from saprophytic forms; however, suspect *Neisseria* were subjected to additional tests.

(15) *Aeromonas and Other Oxidase-Positive Fermenters*

During the course of isolation of colonies (from enrichments and from the selective enteric media) for characterization of the *Enterobacteriaceae*, it became apparent that a major portion of the organisms were oxidase-positive. The procedures described here and in Section (16) were carried out to identify these organisms. The properties of both groups of organisms and appropriate tests for their characterization were obtained by consulting the most current edition of *Bergey's Manual*, and other sources.

The genera of oxidase-positive, Gram-negative fermenters which grow on the various enteric isolation media include *Aeromonas*, *Vibrio*, *Plesiomonas* and *Chromobacterium*. The oxidase-positive-fermenting organisms were characterized (not to the species level) by the four-tube screen and the additional tests summarized in Figure D-14. Organisms that were nonmotile or indole negative in the MIO medium were retested for motility in wet mounts and for indole production in tryptone broth.

(16) *Gram-Negative Nonfermenters-*

The Gram-negative nonfermenting organisms were characterized by the four-tube screen and additional tests shown in Figure D-14. It should be noted that results from this group in the MIO medium were unreliable due to little or no growth in this medium. When necessary, motility was retested in wet mounts and indole production retested in tryptone broth. Oxidative activity for glucose was determined in sealed and unsealed tubes of OF medium. The production of fluorescent pigment was determined by streaking the organisms to sectors of *Pseudomonas* F agar, and gas production from nitrite was determined as described in references. On the basis of the tests used, the Gram-negative nonfermenting organisms were separated into four groups.

(1) Fluorescent pseudomonads
(2) Oxidase Positive Glucose Oxidizers (other than 1)
(3) Alcaligenes and other oxidase positive glucose inactive
(4) Acinetobacter and other oxidase negative

(17) *Respiratory Viruses*

Among the several respiratory tract-associated viruses which could be sought with some probability of success in wastewater samples are adenoviruses (shed in stools), mumps virus (in urine), REO viruses (in stool), herpesviruses (HSV 2 is shed in urine, especially in cystililitis; cytomegalovirus (shed in urine), measles virus (shed in urine). Neither influenza nor parainfluenza nor respiratory syncytial, nor rubella nor rhinoviruses are known to be shed in urine or feces. Although these latter viruses also are transmitted by the oral-respiratory route the best information available suggests strongly that they will not be recovered from urine or feces.

A general outline of attempted isolation, cultivation and identification of respiratory tract-associated viruses is provided in Figure D-17 and Table D-20. All samples were frozen, packed and shipped in dry ice. Concentration from wastewater was via the bentonite method, starting with two separate 10-liter samples of wastewater. First, however, solids were centrifuged from the wastewater sample and triturated in tryptose phosphate broth to enhance recovery of viruses associated with them.

Roller tube cultures were used for all primary isolations, Isolates for typing were obtained from fetal skin and muscle (s 10), Green Monkey kidney (s 1), human embryonic kidney (s 7, s 8, x 4). These are all available as primary isolates and—with one exception—as first subculture. Other cells used were HEp 2 and primary human embryonic kidney. Prior to inoculation into roller tubes, the concentrates (supernatants or extracts of solids) were treated with anti-poliovirus serum pools at levels sufficient to neutralize 95 percent of all poliovirus in 15 minutes.

b. *Aerosols*

(1) *Routine Indicator Organisms*

The routine indicator organisms in the biological analysis of aerosol samples are identical to those defined for analysis of wastewater samples, with the exception of coliphage.

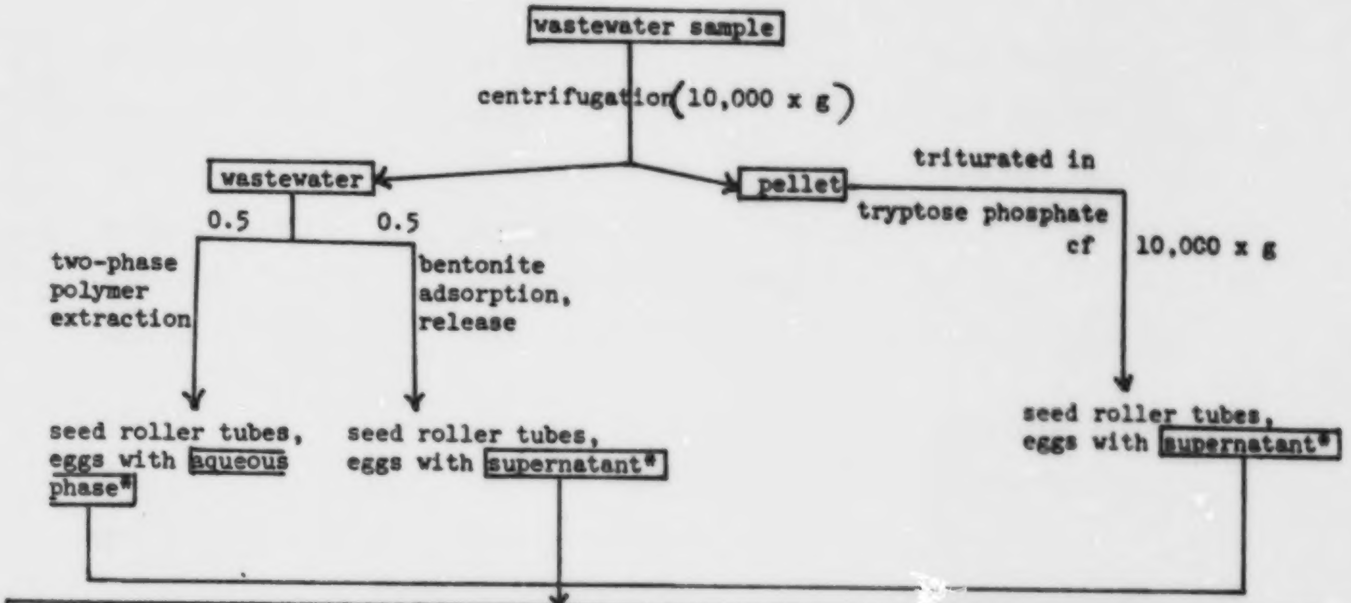
For coliphage, the total available volume of BHI + 0.1-percent Tween 80® (25ml) was plated in a manner similar to that described earlier. The only procedural change was that the 25-ml sample was distributed over twenty 100-mm plates, rather than used for effluent samples.

(2) *Selective Organisms*

(a) *Viruses*

Due to the volume of aerosol collection fluid available for assay in Pre-Fair (25 ml) no concentration procedure was used. The entire volume was assayed as described above except that each 1.0 ml of sample was used to inoculate HeLa monolayers on 100-mm plates. The sample was seeded on the HeLa monolayers in the presence of 2X antibiotics. After 60 minutes for attachment, the inoculum was removed by aspiration and the infected monolayers rinsed twice with HBSS with 2X antibiotics prior to overlaying with agar. Approximately 50-percent of the plates were incubated for three days and scored while the remaining number of plates were incubated for five days and scored.

Figure D-17
ASSAY SCHEME, IDENTIFICATION OF RESPIRATORY VIRUSES IN WASTEWATER


wastewater sample
centrifugation (10,000 x g)
wastewater
pellet
0.5
0.5
two-phase polymer extraction
bentonite adsorption, release
triturated in tryptose phosphate
cf 10,000 x g
seed roller tubes, eggs with aqueous phase*
seed roller tubes, eggs with supernatant*
seed roller tubes, eggs with supernatant*

periodic microscopic examination of cell sheets accompanied by confirmatory tests (as indicated below) on all positive roller tubes; HA and HAI, tests on embryonated eggs; negative GMK tubes subcultured to six tubes: three to be challenged with ECHO 11 (Rubella): and three tubes to be used for HAdI (parainfluenza); (*supernatant to be mixed with pooled antisera, using Lim-Benyesh-Melnick scheme; if adenovirus overgrowth seems likely, antiserum pools will be utilized to suppress these viruses in selected tubes; information on adenovirus prevalence should be available from earlier wastewater analyses)

Table D-20
HOSTS OF CHOICE AND CONFIRMATORY TESTS

VIRUS	HOST CELL 1st/2nd/3rd choice	CONFIRMATORY TEST(S)
adeno	HEK*/HELA/KB	nuclear cytopathology, HAI
mumps	HEK*/CEF	hermadsorption, HAI with amniotic fluid-containing virus
REO	HEK*/HELA/BSC-1	HAI
HSV	HEK/primary RK	neutralization
CMV	Human embryonic skin, muscle	cytopathology, CF
measles	Human kidney, primary	cytopathology, HAI
influenza	embryonated chick egg/MK	HA, HAI
parainfluenza	MK, rhesus	HAdI (on blind passage)
respiratory syncytial	HEp-2	syncytia formation
rubella	GMK**	ECHO II challenge
rhinoviruses	WI-26/HEK*	acid lability

*HEK = human embryonic kidney
**GMK = African Green Monkey kidney

Any areas of cytopathetic effect (CPE) having characteristics of viral infection, at three days and five days post infection and not directly attributable to microbial contamination, were isolated using capillary pipettes. Hanks' balanced salt solution containing 1X antibiotics (Penicillin and Streptomycin, Gentamicin®, and Fungizone®) was added to each tube at 0.5 ml/tube. Such isolates were held at 4°C for at least 24 hours before infection of tube cultures.

Confluent monolayers of HeLa cells grown in stationary tube cultures were infected with 0.2 ml of potential viral isolates. After an infection period of 1.5 hours during which time the inoculum was periodically redistributed over the cells, the inoculum was removed and 3 ml of pre-warmed maintenance media containing 1X antibiotics was added. Infected cultures were returned to a 37°C incubator.

Tubes were observed for CPE under 40X magnification on a daily basis over a period of five days. Any tubes showing destruction of the cell monolayer were harvested by three cycles of alternate freezing-thawing using a dry ice-ethanol bath and a 45°C water bath. Cellular debris was pelleted by low-speed centrifugation in an IEC centrifuge. Supernatants were collected (pH adjusted with $NaHCO_3$) and stored at 4°C. This procedure constituted first passage of isolates. Tubes which showed no CPE at five days were harvested as described and passaged as "blind" isolates.

Uninfected controls also were harvested and served as second passage controls.

Prior to infection of cells for second passage, all first passage supernatants were diluted approximately 1:2 with 1X HBSS and centrifuged at 15,000 × g (11,000 RPM) for 15 minutes in a Sorvall SS-34 rotor. Supernatants from this "high-speed" centrifugation were transferred to sterile tubes and stored at 4°C.

Confluent monolayers of HeLa cells were infected with first passage supernatants (0.2 ml/tube). After a 1.5-hour attachment period, the inoculum was removed and 3 ml of maintenance media containing 2X antibiotics were added. Infected cultures were returned to 37°C CO_2 incubator. Cultures were observed on a daily basis for CPE and handled as previously described. Any tubes harvested as positive from second passage were subjected to further verification by a 3-day and 5-day plaque assay.

Since potential viral isolates were originally selected from "plaque-like" areas, this allows confirmation of the agent passaged through tube cultures.

For the Post-Fair special virus runs, it was necessary to develop methods for handling the large volume to be analyzed. Several concentration procedures were presented as feasible alternatives for the recovery of enteroviruses from large volume aerosol samples (suspending media, BHI containing 0.1% Tween 80®). Of the proposed methodologies, four were selected for preliminary feasibility studies. Parameters evaluated included ease of operation and time required for concentration, volume reduction, virus recovery, and reproducibility of results.

Two viruses were used to evaluate recovery efficiencies, poliovirus I (Chat) and Coxsackievirus B-3. Both viruses were enumerated by plaque assay in HeLa cell monolayers.

- **Ultrafiltration**

Ultrafiltration through a Nucleopore membrane in an Amicon Diaflo stirring unit filtration chamber has been rejected as a feasible methodology in this situation. Because of the size of enteroviruses (25-30 μm), their pressure concentration above polycarbonate membranes dictates the use of pore diameters of 50 nm. Flow rates achievable for this membrane would require as long as 72 hours to concentrate a 100 ml volume.

- **Two-phase aqueous polymer systems**

Two-phase aqueous polymer systems based on dextran and polyethylene glycol (PEG) were examined for the recovery of poliovirus I (Chat) from BHI with 0.1% Tween 80®. In addition to the original system used by Albertsson(87), a modified system substituting dextran 1-500 for sodium dextran sulfate (Na-DS) as developed by Grindrod and Cliver[88] also was evaluated. The concentration systems, recovery of poliovirus I (Chat), and volume reduction (reported as concentration factor) are presented in Table D-21.

Because of superior viral recovery, the traditional two-phase aqueous polymer system utilizing 0.2 percent sodium dextran sulfate, 6.5 percent polyethylene glycol 6000 and 0.15 M sodium chloride was retested using both poliovirus I (Chat) and Coxsackievirus B-3. Results shown in Table D-22 indicate that reasonable recoveries of both enteroviruses may be expected with this procedure.

Limitations of this particular system have been reported by Grindrod and Cliver[89]. While they observed efficient concentration of seven enteroviruses into the lower phase, three viruses (Coxsackie A-9, Coxsackie B-2 and ECHO 6) were strongly inhibited in a plaque assay system by components in the lower phase.

Table D-21
TWO-PHASE AQUEOUS POLYMER SYSTEMS

System	Viral Recovery (%)^a	Concentration Factor^b
0.2% Na-DS 6.5% PEG 6000 0.15 M NaCl	54	132
0.2% Na-DS 6.5% PEG 6000 0.3 M NaCl	18	153
0.2% Dextran T-2000 6.5% PEG 6000 0.3 M NaCl	28	131
0.25% Dextran T-500 7.0% PEG 6000 0.15 M NaCl	26	84
0.25% Dextran T-500 7.0% PEG 6000 0.3 M NaCl	23	95

a % of input virus detected in the lower phase

b concentration factor = $\frac{\text{original volume (ml)}}{\text{lower phase volume (ml)}}$

- *Lyphogel dewatering*

Lyphogel (Gelman Instrument Co.) was added directly to BHI + 0.1% Tween 80® containing poliovirus I (Chat). The reduced fluid volume was collected after 12-18 hours at 4°C. The expanded Lyphogel was rinsed with 3 percent beef extract in 0.1 M Tris buffer at pH 9. Both aliquots were assayed for viral infectivity. Results presented in Table D-22 show 20-24 percent viral recovery in the concentrated volume with an approximate 7-fold volume reduction.

- *Hydroextraction*

Polyethylene glycol (PEG) hydroextraction was used to dewater samples containing both poliovirus I (Chat) and Coxsackievirus B-3. Dialysis tubing with an average pore size of 24 Angstroms was filled with the test volumes, packed in PEG 6000, and held at 4°C for 12-24 hours. After collecting the concentrated volume, the tubing was rinsed with 3 percent beef extract in 0.1 M Tris buffer at pH 9. Once again, both volumes were assayed for viral infectivity. Viral recoveries in the concentrate ranged from 36 to > 100 percent with 5- to 25-fold volume reduction. (The degree of sample reduction is a time dependent function; by 24 hours in one test series, less than 0.2 ml concentrated volume was recovered. Unfortunately, at this level of dewatering, virus recovery was poor.)

Of the methodologies outlined above, only two could be recommended for field use on the basis of the parameters considered. Two-phase polymer concentration gave the best volume reduction while allowing viral recoveries in the range of 50 percent. Additionally, the liquid partitioning system may be expected to exclude a certain number of microbial contaminants from the concentrated lower phase volume containing enteroviruses. However, the limitations inherent in this procedure must be kept in mind. Certain enteroviruses may be excluded from detection by system components. Further, it is essential that the lower phase(s) concentrated volume(s) be diluted before plating for enteroviruses in order to minimize the toxicity toward cell monolayers and the inhibition of plaque formation. Maximum sample volumes which can be handled on a batch basis is limited to 2 liters by the size of commercially available separatory funnels.

Polyethylene glycol hydroextraction also may be considered a viable field procedure. Viral recoveries of 40-50 percent may be expected with 25-fold volume reductions. The simplicity of this concentration technique is advantageous. However, the maximum batch volume handled is limited by the size of dialysis tubing. Thus, the two-phase polymer method was chosen for this study.

(b.) Bacterial Analyses

The methods employed in bacterial analyses for aerosol samples were in general identical to those employed in the analyses of effluent samples, with the exception that sample volumes were larger for the aerosol samples. Other variations are noted below.

(1) *Fecal Streptococci*

The procedures used for the assay of fecal streptococci from aerosol samples were identical to those employed in the analysis of wastewater samples, except that the direct spread plate technique was used in parallel.

(2) *Mycobacteria*

Initially, the procedures used for detection of mycobacteria were identical to those described above. The first results (which become available approximately six weeks into the study) indicated that these methods lacked the sensitivity necessary to provide quantitative data. Thus, sample processing procedures were modified to improve minimum sensitivity as follows:

Table D-22
VIRUSES RECOVERY FROM BHI + 0.1 TWEEN 80®

Concentration System	Input		Recovery			Concentration Factor
	Volume (ml)	Total pfu	Volume (ml)	Total pfu	%	
Poliovirus I (Chat)						
Lyphogel	20	2.6×10^3	2.7	5.1×10^2	20	7.4
(Rinse*)			10.0	8.0×10^2	31	
					51	
Lyphogel	20	2.6×10^3	3.0	6.3×10^2	24	6.7
(Rinse*)			10.0	3.5×10^2	13	
					37	
PEG hydroextraction	50	6.5×10^3	2.0	2.8×10^3	43	25
(Rinse*)			5.0	2.3×10^2	4	
					47	
PEG hydroextraction	50	6.5×10^3	2.2	3.5×10^3	54	23
(Rinse*)			5.0	2.5×10^2	4	
					58	
PEG hydroextraction	50	6.5×10^3	2.0	2.6×10^3	40	25
(Rinse*)			5.0	2.3×10^2	4	
					44	
PEG hydroextraction	50	6.5×10^3	16.3	7.0×10^3	108	3.1
(Rinse*)			5.0	5.0×10^1	<1	
					108	

Table D-22 (cont'd)

Concentration System	Input Volume (ml)	Input Total pfu	Recovery Volume (ml)	Recovery Total pfu	%	Concentration Factor
Poliovirus I (Chat)-cont.						
PEG hydroextraction (Rinse*)	50	8.0×10^3	6.3 5.0	7.6×10^3 3.3×10^2	95 4 99	7.9
PEG hydroextraction (Rinse*)	50	8.0×10^3	9.5 5.0	7.6×10^3 4.3×10^2	95 5 100	5.3
Two-phase polymer w/ Na-dextran sulfate	185	3.0×10^4	1.4	1.3×10^4	54	132
Two-phase polymer w/ Na-dextran sulfate	185	2.6×10^4	1.5	1.4×10^4	47	123
Coxsackie Virus B-3						
PEG hydroextraction (Rinse*)	50	2.3×10^3	7.5 5.0	8.3×10^2 1.8×10^2	36 8 44	6.7
PEG hydroextraction (Rinse*)	50	2.3×10^3	7.5 5.0	9.8×10^2 1.3×10^2	43 6 49	6.7
Two-phase polymer w/ Na-dextran sulfate	185	8.3×10^3	1.4	5.2×10^3	63	132

* Rinses with 3% beef extract in 0.1 M Tris buffer @ pH 9.0.

A sample volume of 9.7 ml was mixed with 0.3ml Zephiran® to give a final concentration of 500 mg/l benzalkonium chloride and held for a minimum of 20 minutes. This treated sample then was centrifuged at 3000 × g for 20 minutes. The resulting pellet was resuspended in phosphate buffered saline and plated in its entirety onto Middlebrook 7H10 agar. Plates were incubated in a CO_2 environment and subsequently handled as previously described. This procedural modification resulted in lowering the detection sensitivity to 10 colony-forming units per 100 ml of sample.

(3) *Large-Volume Microbial Chracterization*

The methods employed in determining the microbial characterization for the large-volume aerosol samples were identical to that employed for the large-volume effluent samples.

C. Quality Assurance

1. Purpose

The nature of the program made it imperative that an extensive quality assurance program be instigated. In attempting to determine if wastewater measurements can be used to predict when a potential health hazard exists in spray irrigation, it is necessary to insure that all measurements that are taken accurately and precisely reflect the actual levels of the water quality indicators and microbiological components of both the wastewater and the aerosol samples collected.

During the Pre-Fair study there were two primary objectives of the quality assurance program.

- To determine the accuracy and precision of laboratory analyses
- To determine if there were systematic differences in high-volume sampler collection efficiency.

Upon evaluation of the Pre-Fair data, it was decided that the quality assurance studies conducted on the wastewater samples had provided sufficient information on the laboratories to give confidence in their performance. Additional aerosol quality assurance runs were scheduled for the Post-Fair study to allow the precision of the mycobacteria analyses, added in Pre-Fair, to be estimated and to obtain more information on the fecal streptococci and coliphage methods, for which only a minimum amount of information was obtained in the Pre-Fair study.

2. Scope

To accomplish the objectives of the accuracy portion of the Quality Assurance Study on the effluent analyses, sealed ampuls of Demand Reference Standards and Nutrient Reference Standards were obtained from the Analytical Quality Control Laboratory of the Environmental Protection Agency in Cincinnati, Ohio. At the time of the request, SwRI personnel were able to obtain only one set of the Demand Reference Standards (high and low levels) and four sets of the Nutrient Reference Standards (high and low levels). The chemical compounds used in these concentrates are listed in Table D-23.

Table D-23
CHEMICAL COMPOUNDS OF EPA REFERENCE STANDARD DEMAND AND NUTRIENT CONCENTRATES

A. **Nutrient Concentrates**

Concentrate 1 (low-level) > spikes for NO_3-N and NH_3-N
Concentrate 2 (high-level)

1. KNO_3 (potassium nitrate)
2. NH_4Cl (ammonium chloride)
3. KH_2PO_4 (dihydrogen potassium orthophosphate)

Concentrate 3 (low-level) > spikes for total P and TKN
Concentrate 4 (high-level)

1. NH_2CH_2COOH (glycine)
2. $Na_2C_3H_7O_6P \cdot H_2O$ (sodium beta glycerol phosphate)

B. **Demand Concentrates 1 & 2** (spikes for BOD, COD and TOC)

1. $C_6H_{12}O_6$(glucose)
2. $C_3H_5(NH_2)$ $(COOH)_2$ (glutamic acid)

In order to make the necessary four liters of effluent for a spiked sample, spikes for all parameters except TOC were made in two-liter volumetric flasks by adding a known amount of the standard sample using a Class A volumetric pipette. After thorough mixing, the samples were distributed to the correct size container with the proper preservative when required. All analyses for each sample container were conducted on spiked and unspiked accuracy samples to prevent bias of the analytical method for the spiked component. Labels were applied randomly to the samples so that a sequence or pairing of the samples could not be determined by the analytical laboratory. A grab sample was taken from pond number 2 for the effluent sample to be spiked whereas deionized water with a specific resistivity of more than one megohm was used for the spiked deionized water.

The TOC spikes were made in 200 µl volumetric flasks using the same background waters as used for the BOD and COD spikes.

The high-level ampul from the single set of Demand Reference Standards was used for spiking one set of eight samples which consisted of two unspiked and two spiked one-liter effluent samples and two spiked and two unspiked one-liter deionized water samples for both the standard laboratory and the alternate laboratory analyses of BOD and COD. The contents of the low-level ampul were used for TOC spiking. Unfortunately, this part of the quality assurance study could not be repeated due to the lack of additional sealed ampuls of the Demand Reference Standards.

The four sets of Nutrient Reference Standards were used at two different times to determine the accuracy of the total P, ammonia-N and nitrate-N analyses of both the standard lab and the alternate lab. In order to provide the necessary amount of spiked sample at a high enough level in two each one-liter bottles to two different laboratories, it was necessary to use the high-level concentrates from two sets of standards. The low-level standards were unusable since the increase of an analyzed parameter would average less than 5% on a spiked sample over that of the unspiked sample. Due to the limited number of high-level standards available, this portion of the quality assurance study would only be performed twice.

Comparative accuracy between the primary and alternate laboratories was obtained on those analyses for which no reference material was available for spiking purposes. For total solids and TSS, hardness, pH, a series of replicate samples was sent to each laboratory for analysis. For nitrate and organic nitrogen, the data were obtained from the analyses on the Total Phosphorous and COD studies. As mentioned above, all analyses normally conducted on a sample bottle were conducted on the quality assurance samples, so that comparative analyses of these two parameters were obtained from the quality assurance samples for Total Phosphorous and COD.

To ensure that the measurements of dye concentration made on both the effluent and the aerosol dye samples were representative of the true concentration, a study was conducted using simulated samples at known concentrations. The samples were prepared using a basic stock solution of dye and the medium in which the actual samples would be analyzed, i.e., deionized water for the aerosol samples, and effluent for the grab samples. Samples were randomized to ensure that the analyst did not know at which level he was working.

For the aerosol simulation, a total of 18 sample portions were prepared, with 2 blanks and 4 portions at each of 4 concentrations: 1.8, 18, 72 and 360 μg/l.

Precision studies were conducted to determine the within-laboratory precision variation introduced during analysis that was associated with each chemical analysis. A large grab effluent sample was taken, thoroughly mixed, and subdivided into six standard-sized sample portions for each group of chemical parameters (routine, selective preserved and selective non-preserved). Samples were then iced down to 4°C and preserved where required. Each sample portion was then analyzed along with the other daily composite samples. Labels were applied randomly to all samples to eliminate any analytical bias caused by an attempt at an orderly arranging of samples. In order to obtain the best possible results under sixfold increase in sample load, all involved laboratories were given 24-hour notice of the impending analytical load.

The Pre-Fair aerosol quality assurance runs were designed to provide information on the precision of the routine bacterial analyses, both within and between samplers, and to determine if systematic differences existed in the sampler collection efficiencies of the various high-volume samplers.

There were five aerosol quality assurance runs during Pre-Fair. On each of these, all functioning samplers were set at the same distance from the spray field approximately 1-meter apart, and the arrangement was randomized so that the samplers were operating on both the right and left sides of the center line, and both on edges and in the middle of the array as well.

A schematic of the plan for aerosol sampling is shown in Figure D-18. The organism level is estimated by the field observer according to the solar radiation, stability class, etc. There are four possible dispositions of the 100-ml aerosol sample. The designation R is used to indicate that four sample portions are to be sent to PEL for replicate analyses of the indicator organisms; A is used to indicate that two are to be sent to

Figure D-18
PRE-FAIR AEROSOL QUALITY ASSURANCE STUDY DESIGN

Run	Organism Level	DISPOSITION OF ALIQUOTS* Sampler Position 1	2	3	4	5	6	7	8	9
1	Low	R	A	R	A	R	A	R	A	
2	Moderate	A	R	A	R	A	R	A	R	
3	High	3	A	3	A	3	A	3	A	A
4	High	U	U	U	U	U	U	U	U	U
5	High	U	U	U	U	U	U	U	U	A

* R - 4 portions to PEL
A - 2 portions to PEL, 2 to EQA
3 - 3 portions to PEL, 1 to EQA
U - 1 portion to PEL, 3 to UTSA

PEL and two to EQA, as an accuracy check; 3 indicates three portions are sent to PEL and one to EQA; and U is the usual disposition, one to PEL for COLI (total and fecal coliform and standard bacterial plate count) and three to UTSA for coliphage, pathogenic bacteria and viruses.

The replicate COLI analyses provide the basis for the within-sampler precision investigation of the COLI analyses and allow the samplers to be checked for collection efficiency bias. The A and 3 forms provide an assist on the above, plus a comparative analysis between the two laboratories. The U analyses allow a measure of precision to be estimated with respect to the coliphage and selected pathogenic bacteria and viruses, as well as aiding the investigation of potential collection efficiency bias.

During the Post-Fair sampling period, three quality assurance aerosol runs were made. They are M2-8-9, M2-18-21, and M2-27-28. The samples from the first and third quality assurance runs were sent to UTSA; those from the second run went to PEL. The two UTSA quality assurance run samples were each divided into two portions. The PEL quality assurance run samples were divided into four portions. On the UTSA quality assurance runs, the 100 ml of the BHI fluid from a sampler was split into a 60 ml portion (labeled the first run) and a 40 ml portion (labeled as the second run). The 60 ml portion was analyzed as usual for coliphage, fecal streptococci, and mycobacteria. The 40 ml portion was analyzed in duplicate for mycobacteria (9a and 9b and 28a and 28b on Table VI.B-14), and singly for coliphage or fecal streptococci. On the PEL quality assurance run, all four 25 ml portions were divided into two aliquots by the lab, and each aliquot was analyzed for total coliform and standard bacterial plate count.

D. Aerosol Sampling Protocols

1. Microbiological Aerosol Runs

a. *Sampling Design—Pre-Fair*

The design of the aerosol sampling for Pre-Fair was a critical part of the overall study and had a significant impact on the manpower requirements for the program. Eight (when available) high-volume air samplers (LEAP and Litton Model M) were utilized for each sampling run. One of these was located upwind and seven downwind.

The aerosol sampling during the Pre-Fair monitoring emphasized close-in stations. The objective was to characterize source strength. The study also emphasized the characterization of bacterial and viral pathogens present in the aerosols. The samples collected close to the spray lines provided the maximum concentration of the pathogens. The use of high-volume samplers at all stations provided uniform sensitivities, and improved the quantitation over that obtained in Phase I. These samplers also provided a large volume of air for the assay.

The protocol, as designed, called for 20 sampling runs with eight high-volume samplers to be used for each run. The samples were collected simultaneously. This improved the quality of the aerosol data significantly over the sequential sampling conducted during Phase I. This was particularly true because of the variable wind conditions in the Pleasanton area. Routine and selective microbiological assays were made on all samples collected (high-volume samplers). This was necessary to fully describe the relationship between routine microbiological parameters and selective parameters.

The downwind aerosol samplers utilized in the Pre-Fair aerosol sampling runs were arranged as a sampler line, that is, perpendicular to the line formed by the operating sprayers. The standard configuration of the seven downwind high-volume samplers relative to the sprayer line is depicted in Figure V.D-1. These downwind samplers were located at 5 meters, 10 meters, side-by-side at 20 meters, at half the maximum distance and side-by-side at the maximum distance from the wet-line edge. The maximum distance was determined for each run in Step e of the Sampling Decision Procedure shown below. The maximum distance was most frequently 100 meters. It should be noted that the sampler line was always perpendicular to the sprayer line, regardless of the angle, θ, that the mean wind direction made with the sprayer line.

After the eighth aerosol run, the 5 meter station was eliminated and moved to 30 meters due to the frequency at which the 5 meter station was hit with spray during wind gusts. Also, the last five runs used a different array in that all samplers were located as shown in one of the two following configurations.

CONFIGURATION A		CONFIGURATION B	
No. of Samplers	Distance	No. of Samplers	Distance
1	upwind	1	upwind
2	10 meters	3	20 meters
1	20 meters	1	30 meters
1	30 meters	2	50 meters*
2	50 meters	1	40 meters*
1	40 meters*		

* double samplers at these distances were alternated on different runs.

The upwind high-volume sampler was located at a distance of several kilometers on a wooded hill elevated at least 100 meters above the spray fields to sample background microbiological levels.

When less than eight aerosol samplers were available for a run, one of the duplicated side-by-side samplers at both the maximum distance and at the 20 meter locations was the first sampler position to be left vacant for such runs.

The sampling configuration shown in Figure V.D-1 was located in any of three positions (at the center of sprayer line or near either side) when making the aerosol run. The positions of the downwind sampler line are presented in Figure D-13 both for the long single sprayer line when sampling in fields B, C, or D and for the shorter double sprayer lines when sampling in fields 0, 1, 2, 3, or 4. The selection of the position for the sampler line depended primarily on the mean wind direction and secondarily on the Pasquill wind stability class. This selection was made according to the Sampling Decision Procedure below. When a side position was used, it was the side for which the sampler line was most frequently downwind of some portion of the sprayer line. The procedure was as follows:

PRE-FAIR SAMPLING DECISION PROCEDURE

1. *Field Measurement of Wind Direction*

   Determine θ, the angle of the mean wind direction with the sprayer line, to the nearest 5° from the field wind measurement strip chart recorder just before the aerosol sampling run.

2. *Field Determination of Wind Stability Class*

   Obtain the wind stability class in the field by one or more of the following procedures (listed in decreasing order of reliability):

   a. from the temperature difference instrumentation (4.7m vs. 0.5m):

Reading	Interpretation	Stability Class
+	Stable	E or F
0	Neutral	D
—	Unstable	A, B or C

   b. from the solar altitude, wind speed and cloud cover as described by D.B. Turner in Atmospheric Dispersion Estimates:

Key to Stability Categories

	Day			Night	
Surface Wind Speed (at 10 m) m sec⁻¹	Incoming Solar Radiation			Thinly Overcast or ≥4/8 Low Cloud	≲ 3/8 Cloud
	Strong	Moderate	Slight		
<2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D

The neutral class, D, should be assumed for overcast conditions during day or night.

c. from the variability in wind direction.

3. *Decision to Set Up for a Run*

Do not conduct a sampling run in Field A or in Field B if the sampled upwind air stream passes over Interstate 680 within 300 meters of the samplers. If there is a choice, Fields B, C and D should be given preference over Fields 0, 1, 2, 3, and 4 for aerosol sampling. In Fields B, C and D, determine whether to set up for an aerosol run from Table D-24. In Fields 0, 1, 2, 3 or 4, use Table D-25 to determine whether to set up. For the current mean wind angle θ and stability class, set up for the run if the decision table entry is C or S; do not set up for aerosol sampling if the table entry is N. Do conduct a dye run if the mean wind angle θ is less than 45°. Tables D-24 and D-25 were constructed based on sampler configuration trigonometry and on the criterion that the maximum distance sampler(s) be placed at least 50 meters from the wet-line edge and that they be downwind of some portion of the sprayer line at least 83 percent of the time.

4. *Selection of Sampler Line Position*

Refer to Tables D-24 or D-25 to choose the position of the line of samplers along the sprayer line. If the decision table entry is C, set up the samplers in the center position. If the entry is S, set up the samplers in the side position that is most frequently downwind of the sprayer line. The C or S position indicated in the decision tables maximizes the downwind probability.

5. *Maximum Distance Determination*

Obtain the maximum distance for locating the "maximum distance" and "half maximum distance" samplers from Tables D-24 and D-25. The maximum distance criteria used to develop the decision tables are that the maximum distance sampler(s) be downwind of the sampler line at least 83% of the time and relatively near (within 200 meters of) the sprayer line.

6. *Decision to Sample*

After setting up for the aerosol run, recheck the wind direction and stability. Sample only if the decision table still calls for sampling and if no marked changes in meteorological conditions are expected over the next 30 minutes.

7. *Decision to Continue/Abort During the Run*

Continue the run if there is no marked change in the mean wind direction. However, if the mean wind direction shifts to become parallel to the sprayer line or reverses to the opposite side of the sprayer line (so the "downwind samplers" are upwind) before 15 minutes of sampling have elapsed, abort the run.

8. *Decision to Ship/Discard Samples After the Run*

The aerosol samples are to be processed and shipped for analysis unless one or more of the following conditions occur:

a. Based on the field strip chart recorder and temperature difference instrumentation, there was sufficient change in the wind direction and/or stability that the maximum distance sampler experienced less than 15 minutes of actual downwind sampling.

b. Aerosol samples are obtained from less than four of the downwind samplers.

c. No upwind aerosol sample is obtained. If the upwind (background) sampler should malfunction during the run, another upwind sample can be substituted provided it is taken within six hours after run completion.

Table D-24
DECISION TABLE FOR AEROSOL RUN SETUP, SAMPLER LINE POSITION AND MAXIMUM SAMPLER DISTANCE

Fields B, C or D (480m Length)

Angle of Wind With Sprayer Line	Stability Class					
θ	A	B	C	D	E	F
10°	N	N	N	N	N	S,50m.
15°	N	N	N	N	S,60m.	S,80m.
20°	N	N	N	S,60m.	S,100m.	S,100m.
25°	N	N	S,60m.	S,100m.	S,100m.	S,100m.
30°	N	S,60m.	S,100m.	S,100m.	S,100m.	S,100m.
35°	S,60m.	S,100m.	S,100m.	S,100m.	S,100m.	S,100m.
40°	S,100m.	S,100m.	S,100m.	S,100m.	S,100m.	S,100m.
45°	S,100m.	S,100m.	S,100m.	S,100m.	C,100m.	C,100m.
50°	S,100m.	S,100m.	S,100m.	C,100m.	C,100m.	C,100m.
55°	S,100m.	S,100m.	C,100m.	C,100m.	C,100m.	C,100m.
60°	S,100m.	C,100m.	C,100m.	C,100m.	C,100m.	C,100m.
70°	C,100m.	C,100m.	C,100m.	C,200m.	C,200m.	C,200m.
80°	C,100m.	C,200m.	C,200m.	C,200m.	C,200m.	C,200m.
90°	C,200m.	C,200m.	C,200m.	C,200m.	C,200m.	C,200m.

NOTATION:
N- do not sample
C- center position, 240m from ends of sprayer line
S- side position, 80m from end of sprayer line

Table D-25
DECISION TABLE FOR AEROSOL RUN SETUP, SAMPLER LINE POSITION AND MAXIMUM SAMPLER DISTANCE

Fields 0,1,2,3 or 4 (320m Length)

Angle of Wind with Sprayer Line	Stability Class					
θ	A	B	C	D	E	F
10°	N	N	N	N	N	N
15°	N	N	N	N	N	S,50m.
20°	N	N	N	N	S,60m.	S,80m.
25°	N	N	N	S,60m.	S,80m.	S,100m.
30°	N	N	S,60m.	S,80m.	S,100m.	S,100m.
35°	N	S,60m.	S,80m.	S,100m.	S,100m.	S,100m.
40°	S,60m.	S,80m.	S,100m.	S,100m.	S,100m.	S,100m.
45°	S,80m.	S,100m.	S,100m.	S,100m.	S,100m.	S,100m.
50°	S,100m.	S,100m.	S,100m.	S,100m.	S,100m.	S,100m.
55°	S,100m.	S,100m.	S,100m.	S,100m.	S,100m.	C,100m.
60°	S,100m.	S,100m.	S,100m.	S,100m.	C,100m.	C,100m.
70°	S,100m.	S,100m.	C,100m.	C,100m.	C,100m.	C,100m.
80°	C,100m.	C,100m.	C,100m.	C,200m.	C,200m.	C,200m.
90°	C,100m.	C,200m.	C,200m.	C,200m.	C,200m.	C,200m.

NOTATION:
N - do not sample
C - center position, 160m from ends of sprayer line
S - side position, 50m from end of sprayer line

b. *Post-Fair Aerosol Studies*

(1) *Microbiological Aerosol Sampling*

The protocol specified that a minimum of eight high-volume aerosol samplers of the LEAP and Litton type be utilized for each aerosol sampling run. Ordinarily one of these samples would be located upwind and the other seven downwind with configurations similar to those utilized during Pre-Fair, except that sampling will be carried out at least to distances of 600 meters downwind of the spray fields. More emphasis was placed on modeling of aerosols concentrations calculation of die-off of individual microorganisms, and prediction of specific microbiological constituents at distances downwind from the spray fields under a variety of meteorological conditions. A total of 30 aerosol runs was planned during the 18-week Post-Fair monitoring program. The protocol is summarized as follows:

POST-FAIR MICROBIOLOGICAL AEROSOL RUN
SAMPLING PROTOCOL

A. *Sampling Configuration*

1. Sampled Spray Fields
   a. Primary: Dry Side (advance of spray line): A-7*, B,C,D
   Wet Side: (behind spray line) D

   b. Secondary: Wet Side: C, B-6, B-7
   NOTE: Secondary sampling will require placing stake line L between Fields A and B.

2. *Equipment — See Figure V.D-2 for placement.*

   a. Eight (8) high-volume microbiological samplers:

   - 1 upwind at the golf course location
   - 2 at 50 meters — paired with 3 meter separation
   - 2 at 100 meters — paired with 3 meter separation
   - 3 at about 600 meters — downwind from center of spray line with potential separations of 200 meters, 250 meters or 300 meters.

   b. Approximately 20 rotorod FP (fluorescent particle) samplers:

   - 10 at about 300 meters from wet-line edge (50 meter sep.)
   - 10 at about 600 meters from wet-line edge, located
     — 1 near each high-volume sampler
     — 1 midway between samplers
     — 3 beyond farther end high-volume sampler (100 meter sep.)
     — 2 beyond more centered end high-volume sampler (100 meter sep.).

   c. FP source, located just downwind of 50 meter high-volume samplers.

   d. 2 meter wind direction and velocity tower, located near 100 meter high-volume samplers.

   e. Temperature and relative humidity instrument, located for 15 minutes both just upwind and downwind of the wetted area.

   f. Measurements of flow rate for each spray head.

g. Effluent temperature measurement.

h. Thirty-minute composite sample of wastewater from the end of the spray line.

3. *Lines of stake locations with 50 meter separation — see Figure V.D-3*

4. *Three potential positions for 50 meter samplers, 100 meter samplers, FP source, and 2 meter tower:*

   a. Center — along main irrigation pipeline.
   b. Right side (when facing spray line) — along a perpendicular line 80 meters in from the right-most spray held.
   c. Left side — 80 meters in from left-most spray head.

5. *Actual sampler position example — see Figure D-19. (example)*

   - Spray line at Field B, setting 2.
   - Dry side sampling
   - Wind angle $\phi = +35°$
   - Right side sampler position

B. *Sampling Decision Procedure*

1. *Sampler Location Procedure*

   a. Determine ϕ, the angle of the mean wind direction relative to the perpendicular to the sprayer line, to the nearest 5° from the 4 meter strip chart recorder at the 102-foot meteorological station.

      (1) Determine the 4 meter strip chart wind direction mean τ for a 5 minute period (aligned to true north = 0° =360°).

      (2) $\phi = 220° - \tau$ (samplers on dry side of field)
      $\phi = 40° - \tau$ (samplers on wet side of field)

   b. Based on the angle ϕ, use Table D-26 to determine:

      (1) If the sampler should be set up (i.e., is ϕ in the indicated range).

      (2) How samplers should be set up:

         - the position of the near samplers (right, center, or left)
         - the letter of the distant sampler line
         - the separation between the distant high-volume samplers
         - the letter of the near rotorod line.

   c. The field supervisor should specify the actual sampler locations using Table D-26 and the following rules:

      (1) The center distant sampler should be located at the stake directly downwind from the middle of the spray line.

      (2) The distant rotorods should be located as follows relative to the farther and more central of the two end distant samplers:

* number refers to location of spray line within field, e.g. seventh setting (seventh day) in field A.

Figure D-19

SAMPLER POSITION EXAMPLE (Spray line in Field B-2, Dry Side Sample Wind Angle ϕ = +35 (right position)

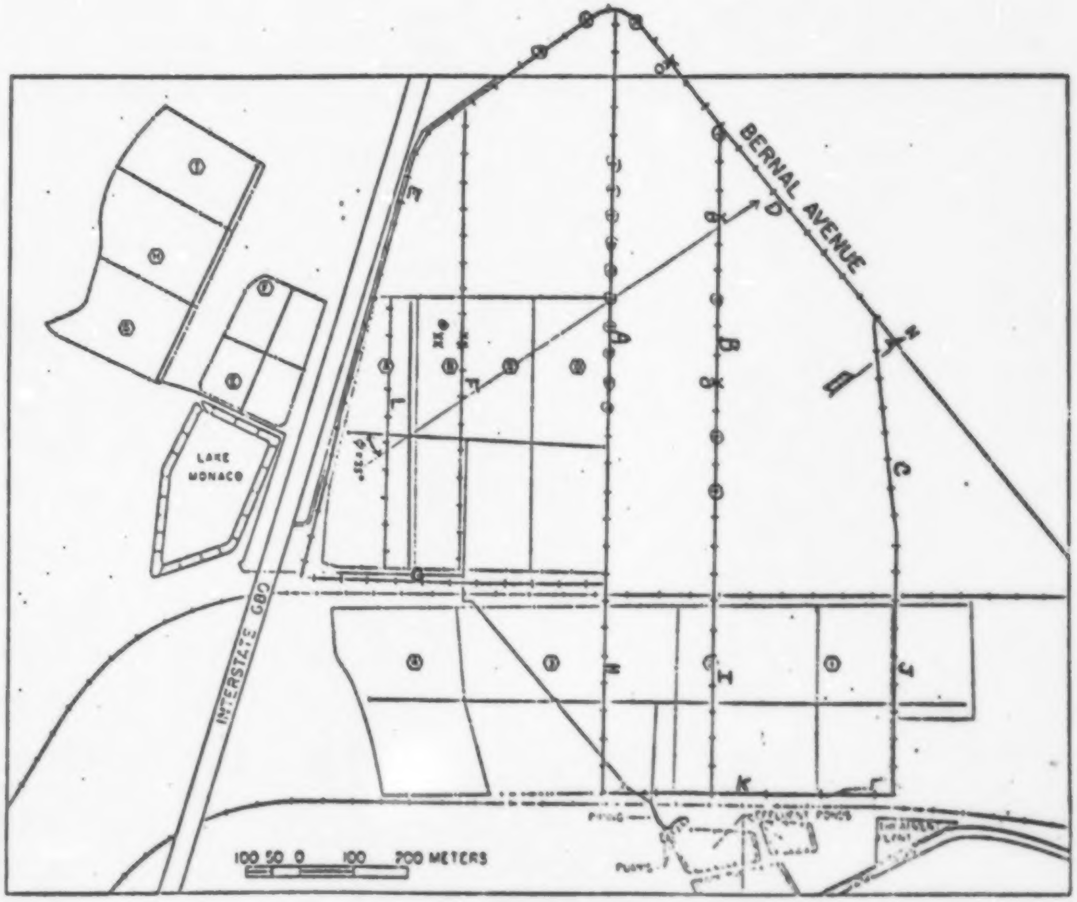

BERNAL AVENUE
A
B
C
D
E
F
G
H
I
J
K
L
N
XX
ϕ=35°
LAKE MONACO
INTERSTATE 680
PIPING
PUMPS
EFFLUENT PONDS
100 50 0 100 200 METERS

Table D-26
SAMPLER LOCATION CRITERIA (Revised)

Sampled Side of Spray Line	Spray Field	Location of 50m and 100m Samplers: Wind Angle ∅	Location of 50m and 100m Samplers: Position	Near Rotorod Line	Distant Sampler Line	Distant Sampler Separation
Primary Sampled Fields						
Wet	D	(-65°, -30°)	Left	F	E	200m
		(-29°, +29°)	Center	F	E	150m
		(+30°, +45°)	Right	F,G	E,G	200m
Dry	A (setting 7 only)	(-45°, -30°)	Left	F,G	A,G	200m
		(-29°, +29°)	Center	A,M	B,H,D	300m
		(+30°, +65°)	Right	F,E	A,E	250m
Dry	B	(-50°, -30°)	Left	A,G	B,H,K	300m
		(-29°, +29°)	Center	A,M	B,H,D	300m
		(+30°, +65°)	Right	A,E	B,D,E	300m
Dry	C	(-65°, -30°)	Left	A,M	H,B,K	300m
		(-29°, +29°)	Center	A	B,H	250m
		(+30°, +65°)	Right	A	B,D,E	300m
Dry	D	(-65°, -39°)	Left	H,B,K	I,K,C	300m
		(-29°, +29°)	Center	B,H	C,D,I	300m
		(+30°, +65°)	Right	B,A	D,C,E	300m
Secondary Sampled Fields (requires stake line L between Fields A and B):						
Wet	C	(-65°, -30°)	Left	L,E	E	150m
		(-29°, +29°)	Center	L,G,E,	E,G	150m
		(+30°, +45°)	Right	L,G	E,G	150m
Wet	B (setting 6 and 7)	(-65°, -30°)	Left	L,E	E	150m
		(-29°, +29°)	Center	L,G	E,G	150m
		(+30°, +45°)	Right	L,G	E,G	150m

- 300 meters beyond the farther end high-volume distant sampler
- 200 meters beyond the farther end high-volume distant sampler
- 100 meters beyond the farther end high-volume distant sampler
- near the farther end high-volume distant sampler
- midway between the farther end and middle high-volume samplers
- near the middle high-volume sampler
- midway between the more centered end and middle high-volume samplers
- near the more centered end high-volume sampler
- 100 meters beyond the more centered end and middle high-volume samplers
- 200 meters beyond the more centered end

(3) For the center position runs, center the 10 near rotorod samplers downwind from the middle of spray line; for the side position runs, place 6 samplers on the outside, and 4 on the inside, downwind of the middle of the spray line (because the FP source is to one side of the spray line).

(4) When the distant and near rotorod lines overlap, the extra rotorod samplers should be placed at the end of the specified lines.

d. When the samplers are located, the field supervisor should determine two sets of critical wind angles as illustrated in Figure D-20.

(1) Wind angle range to initiate run: $\alpha \leqslant \phi \leqslant \beta$ (the mean wind direction carries aerosol from the center of the spray line between the end distant samplers)

(2) Wind angle range for judging good run: $\gamma \leqslant \phi \leqslant \delta$ (the mean wind direction carries aerosol from some part of the spray line to at least one of the distant samplers).

2. *Decision to Begin the Primary Aerosol Run*

After the samplers are set up and ready to sample, begin the 30-minute run after a 5-minute mean wind angle ϕ is in the range: $\alpha \leqslant \phi \leqslant \beta$.

3. *Conduct the Primary Aerosol Run*

NOTE: If the wind direction changes sufficiently during the run that a distant high-volume sampler is downwind of another spray line (in Fields 1, 2, 3 or 4), the supervisor should direct that this sampler be shut down and covered during such times to prevent sampling the wrong line.

4. *Criteria to Analyze Rotorod Samples and to Ship the Microbiological Sample*

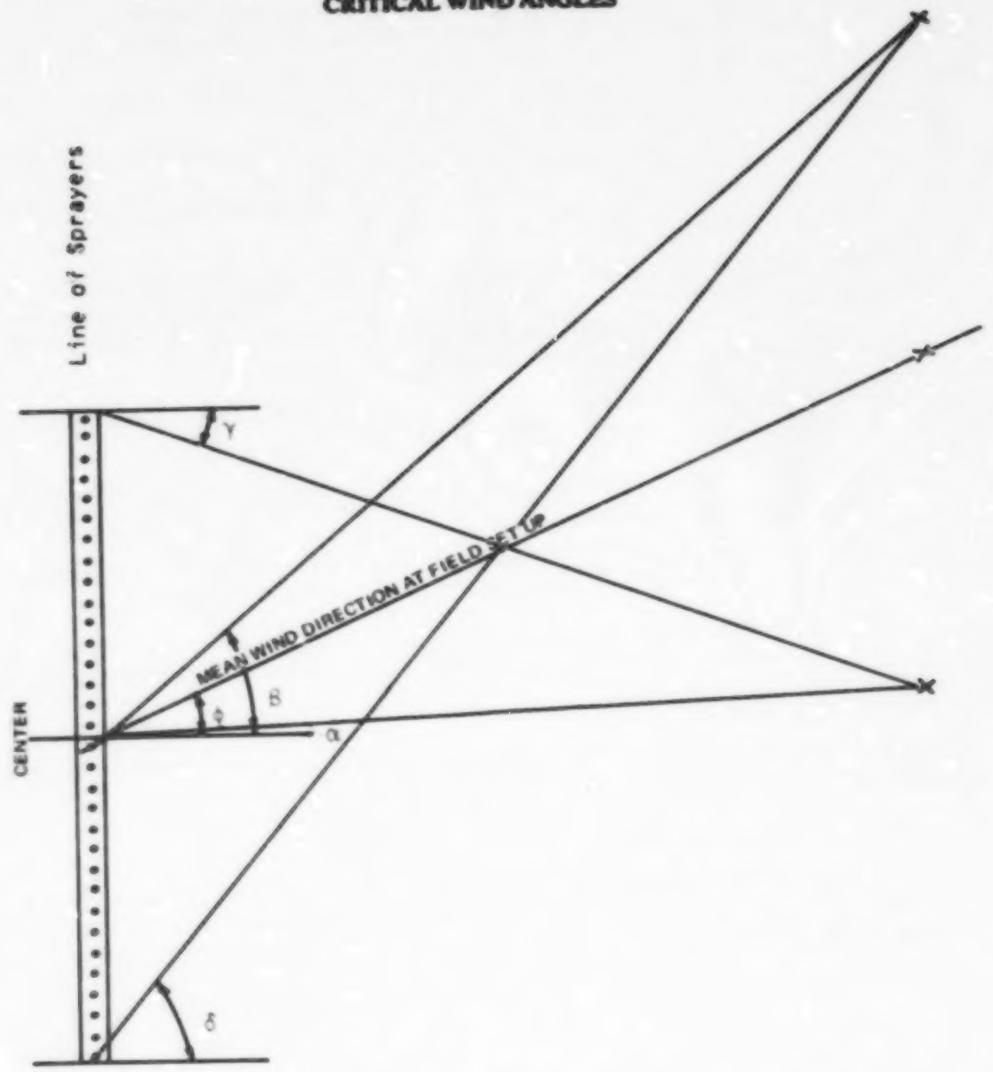
a. *Determine the mean wind direction* τ (from the 4 meter strip chart) for the six 5-minute intervals.

b. The run is good (i.e., the rotorods and high-volume samples should be sent for analysis) if four conditions are satisfied:

(1) $\gamma \leqslant \phi \leqslant \delta$ for at least four of the six 5-minute intervals.

(2) for all six intervals,
$-75^\circ \leqslant \phi \leqslant +40^\circ$ if in left position
$-65^\circ \leqslant \phi \leqslant +65^\circ$ if in center position
$-40^\circ \leqslant \phi \leqslant +75^\circ$ if in right position

Figure D-20
CRITICAL WIND ANGLES



LEGEND

X = distant high-volume sampler position
φ = angle of mean wind direction with perpendicular to the spray line
α = angle of line from distant more centered end sampler and center of spray line with the perpendicular to the spray line.
β = angle of line from distant farther end sampler and center of spray line with the perpendicular to the spray line.
γ = angle of line from distant more-centered end sampler and opposite end of spray line with the perpendicular to the spray line.
δ = angle of line from distant farther end sampler and opposite end of spray line with the perpendicular to the spray line.

(3) Usable aerosol samples are obtained from at least four of the seven downwind samplers.

(4) An upwind sample is obtained during the run or within two hours after run completion.

C. Range of Meteorological Conditions

The desired distribution of meteorological conditions over the 30 good microbiological aerosol runs is shown in Table D-27 as well as for the 16 dye runs. A maximum of four runs was to be achieved in any one category until a total of 30 good runs were obtained.

Table D-27
DESIGN OF MATRICES OF METEOROLOGICAL CONDITIONS

Solar Radiation (Preferred Time of Day)	Relative Humidity (4m level at 102 ft. tower)	Wind Velocity (4m level at 102 ft. tower)	
		Low Mean <3.0m/sec	High Mean ≥3.0m/sec
Microbial Aerosol Runs:			
None or Low Mean <0.3g cal/cm^2 (Night)	Low, <65%	4 runs	4 runs
	High, ≥65%	4 runs	4 runs
High or Moderate Mean ≥0.3g cal/cm^2 (Afternoon)	Low, <40%	4 runs	4 runs
	High, ≥40%	4 runs	4 runs
Dye Aerosol Runs:			
Night (After sunset)	Low, <65%	2 runs	2 runs
	High, ≥65%	2 runs	2 runs
Afternoon (>1 hr. before sunset)	Low, <40%	2 runs	2 runs
	High, ≥40%	2 runs	2 runs

2. Dye Aerosol Runs

a. *Sampling Design*

The Post-Fair dye runs were conducted on a single line of spray heads in Fields B, C, D, 0, 1 and 2, with Fields B, C and D preferable because of their greater length. The configuration of the samplers and meteorological instrumentation in the spray fields is depicted in Figure V.B-3. Paired samplers were to be located at 50, 75 and 100 meters from the wet line edge along the center line of the field with the separation between the paired samplers about 1 meter. Two pairs of samplers were located at 50 meters, one pair on each side of the irrigation line at distances of 7 and 8 meters from the line. The distance from the wet-line edge to the spray head line was measured when setting up for the run. Spray head flow rate measurements (or the number of seconds required to fill a 20-l container) were taken from spray heads 1, 3 and 5 on each side of the irrigation line.

b. *Decision to Conduct and Accept Runs*

The decisions regarding conducting and accepting dye runs were based largely on the mean wind direction τ for 5-minute intervals relative to the main irrigation line (sampler lines). The angle ϕ was determined from the strip chart recorder attached to the 4-meter sensor on the 32-meter meteorological monitoring station. This strip chart recorder and all others were operated at a chart speed of 12 inches/hour just preceding and during each dye and aerosol run. The 5-minute mean wind angle ϕ relative to the irrigation line is estimated from the 5-minute mean wind direction τ from the 4-meter strip chart (aligned to true north = 0° = 360°) as:

$$\phi = 220^\circ - \tau \text{ (Dry side of field)}$$
$$\phi = 40^\circ - \tau \text{ (Wet side of field)}$$

For field estimation, the 5-minute mean wind direction τ was estimated by drawing the best vertical line through one inch (=5 min) of wind direction data.

The sampling decision procedure was as follows:

1. Decision to Sample. When the mean wind angle ϕ is ±45° ($-45^\circ \leq \phi \leq 45^\circ$) [$-40^\circ \leq \phi \leq +40^\circ$ in Fields 0, 1 or 2] for at least a 5-minute period, begin the dye run. Mark the wind direction strip charts of the 4-, 16- and 32-meter station sensors and of the two 2-meter field wind towers with time hacks at the beginning and end of the run.

2. Make time hacks on the 4-meter wind direction strip chart after every 5 minutes of the 30-minute run. If the mean wind angle ϕ for any 5-minute period exceeds + 90°, abort the run.

3. Decision to Analyze Dye Concentration. Analyze the effluent and aerosol dye sample concentrations if all six 5-minute mean wind angles ϕ are within ±75° [±60° in Fields 0, 1 or 2].

4. Acceptance of the Dye Run for Modeling

    a. for at least four of the six 5-minute intervals ϕ is within ±45° [±40° in Fields 0, 1 or 2].

    b. for all six 5-minute intervals, ϕ is within ±60° [±50° in Fields 0, 1 or 2].

    c. estimate ϕ for the two 15-minute intervals from the strip chart for the 2-meter tower next to the 100-meter samplers. For both 15-minute averages, ϕ should be within ±45° [±40 in Fields 0, 1 or 2].

    d. wide range of meteorological conditions (see Table D-27).

3. Quality Assurance Aerosol Runs

The quality assurance activities for the Pre-Fair portion of the study included the conduct of aerosol sampling runs. These runs were designed to provide information on the precision of the routine bacterial analyses, both within and between samplers and to determine if systematic differences existed in the sampler collection efficiencies of the various high-volume samplers.

There were five aerosol quality assurance runs during Pre-Fair. On each of these, all functioning samplers were set at the same distance from the spray field approximately one meter apart, and the arrangement was randomized so the samplers were operating on both the right and left sides of the center lines and both on edges and in the middle of the array as well.

A schematic of the plan for aerosol sampling is shown in Figure D-19. The organism level was estimated by the field observer according to the solar radiation, stability class, etc. There were four possible dispositions of the 100 ml aerosol sample. The designation R is used to indicate that four sample portions are to be sent to PEL for replicate analyses of the indicator organisms; A is used to indicate that two are to be sent to PEL and two to EQA, as an accuracy check; 3 indicates three portions are sent to PEL and one to EQA; and U is the usual disposition, one to PEL for COLI (total and fecal coliforms and standard bacterial plate count) and three to UTSA for coliphage, pathogenic bacteria and viruses.

The replicate COLI analyses provide the basis for the within-sampler precision investigation of the COLI analyses and allow the samplers to be checked for collection efficiency bias. The A and 3 forms provide an assist on the above, plus a comparative analysis between the two laboratories. The U analyses allow a measure of precision to be estimated with respect to the coliphage and selected pathogenic bacteria and viruses, as well as aiding the investigation of the collection efficiency bias.

4. Special Enteric Virus Aerosol Runs

The primary objective of the virus study was to obtain reliable aerosol virus concentration data using specialized sampling methodologies and concentration methods, and to determine if measurement of enteric virus in aerosols downwind from a sprinkler line was practical with state-of-the-art sampling procedures and equipment. Due to the low effluent concentrations of viruses, there were problems in sampling for enteric viruses in the vicinity of the spray irrigation fields in Pleasanton noted in the Pre-Fair study. Thus, even the level of sensitivity available with the high-volume samplers was not sufficient to routinely measure them in air. Insufficient data were therefore available to estimate the ratio of levels of viruses in the air versus similar levels in effluents. Based on the ratios found for pathogenic bacteria and on the Pre-Fair effluent virus concentration, it was estimated that a minimum of 1600 meters of air would have to be sampled, the total sample concentrated, and then the entire sample analyzed to detect viruses in the aerosol sample.

From estimations of data during Pre-Fair and based on the aerosol effluent ratio for *Pseudomonas*, it appeared that the equivalent of 3 to 4 hours of aerosol sampling would be required. This necessitated that the eight high-volume samplers be operated simultaneously for six to eight consecutive aerosol runs in close proximity to each other. The runs consisted of 30-minute sampling periods after which the 100ml of BHI was transferred to a common container and a new aerosol run initiated for an additional 30 minutes. The total quantity of BHI was then transported to the UTSA laboratories, concentration of the BHI was initiated, and analysis of the concentrate for 3-day and 5-day viruses was conducted. The results of these tests would be the basis for the design and conduct of future virus sampling at the site. Effluent grab samples were collected concurrent with aerosol sampling and measured as described earlier. Conditions expected to bring about the highest virus concentrations in the aerosol were determined and are shown in Table D-28.

Table D-28
IDEAL SAMPLING CONDITIONS FOR ENTERIC VIRUS DETECTION

Sampling Condition	Value	Basis
Wind stability	Pasquill class E	
Wind speed	2.0 m/sec	Typical and desirable
Wind direction	Perpendicular to spray line	——
Sampler distance	50 m from wet-line edge	Prescribed for virus runs
Wastewater flow rate from sampled spray heads	90 l/min	Typical

The expected virus concentration in the wastewater was 17 PFU/l based on the geometric mean of the 5-day enteroviruses during Pre-Fair. Wastewater aerosolization efficiency of 1.2 percent was used to calculate the volume of air required, which was a compromise between the SwRI and Cramer analyses of the Pre-Fair dye runs.

E. Data Flow, Processing, and Analysis Methods

1. Sample Identification and Labeling

To develop valid findings from this large-scale field sampling and analysis effort, it is essential that the identity and integrity of the data be preserved. Accordingly, an integrated data system involving a unique sample code, computer-generated sample labels, field data reporting forms, and analytical data reporting forms was implemented. This system insured that each sample was uniquely identified (run number, sample location, medium, analysis, sampling period) and that this identity was transmitted with the analytical values from sample collection through processing, shipping preparation, analysis, reporting, and statistical analysis.

The sample code was devised to provide unique sample identification. It defined the various aspects of a sample portion: the run or sample number; sampling information (aerosol sampler number or effluent sample category and location); the sample medium (effluent or aerosol); the analysis of that sample portion (pathogenic bacteria, dye, coliphage, indicator bacteria, total organic carbon, etc.); the site; the sampling period (Phase I, Pre-Fair or Post-Fair in Phase II); and the project number. The composition and interpretation of this sample code is given in Table D-29. A typical sample code is __615AJPL3__4297. This code identifies the aerosol (A) sample portion from sampler 6 on Post-Fair (3) run 15 at Pleasanton (PL) that is to be analyzed for indicator bacteria (J).

Sample labels were used to affix the sample code to every bottle containing the sample or a portion of the sample. Appearing on the sample label were both the sample code (in the lower left hand corner) and several printed words. The printed words gave enough information to the field and laboratory personnel to properly process, distribute, and analyze the sample without needing to interpret the sample code. Thus the sample labels facilitated correct sample processing, distribution, and analysis while preserving the sample's identity. Typical sample labels are given in Figure D-21. The first label in Figure D-21, which has __8__3AJPL__4297 as its sample code, identifies an aerosol sample portion obtained by sampler 8 on Pre-Fair microbiological aerosol run 3 that is to be analyzed for standard bacterial plate count and total and fecal coliform by PEL.

Special computer programs were written to generate the proper types and numbers of sample labels. The programs also sorted the labels so that they were printed in the sequence that was most convenient for their application to the proper sample containers before and during sample collection and processing in the field. The collected sample often had to be split into several portions at the one-site field laboratory, because several analyses, requiring either differing preservatives or different laboratories, were to be performed. The proper number and type of processing labels were also generated for the bottles containing these processed sample portions.

2. Data Forms and Reporting System

Special forms were developed in collaboration with the field and laboratory supervisors for direct reporting of the field and laboratory data. A cross section of completed data forms from Pre-Fair and Post-Fair are presented at the end of this appendix. As these completed forms illustrate, the relevant parts of the sample code were reported along with the sample data. Approximately every three weeks, the laboratory or field supervisor transmitted a package of completed forms to the statistician. These forms were reviewed immediately to check for data reporting deficiencies and for sampling or analysis problems.

Figure D-21
TYPICAL SAMPLE LABELS

Pre-Fair Labels:

```
PUMP                 GRAB
RUN       3          COLIPHAGE
GP 3EGPL2  4297           UTSA
```

```
SAMPLER  8           AEROSOL
RUN      3           COLI
 8 3AJPL2  4297           PEL
```

```
SAMPLER  8           AEROSOL
RUN      3           ALL
 8 3AVPL2  4297           UTSA
```

```
SAMPLER  4           AEROSOL
RUN      6           DYE
 4 6ADPL2  4297           SWRI
```

```
SAMPLE  20           COMPOSITE
                     PRESERVED
CR20ETPL2  4297           EQA
```

Post-Fair Labels:

```
SAMPLER  2        AEROSOL
RUN      1        COLI
 2 1AJPL34297     PEL
```

```
                  COMPOSITE
RUN      1        UTSA
CR 1EMPL3  4247
```

Table D-29
THE SAMPLE CODE

	Columns	Variable	Values and Interpretation
for aerosol samples	1-2	sampler number	1, 2, 3, ... 12
	3-4	aerosol run number	1, 2, 3, ...
for effluent samples on aerosol runs	1	category	C — 30 minute composite sample G — grab sample
	2	location and time	B — spray nozzle, beginning of run E — spray nozzle, end of run P — pump at holding pond
	3-4	aerosol run number	1, 2, 3, ...
for other effluent samples	1	category	C — daily composite sample LVMC — large volume grab for microbial characterization
	2	analysis frequency	(blank) — routine S — selective
	3-4	sample number	1, 2, 3, ...
	5	sample medium	A — aerosol sample E — effluent (wastewater) sample
	6	sample analysis	B — pathogenic bacteria (fecal streptococci, *Clostridium perfringens*, *Klebsiella*, mycobacteria, *Pseudomonas*) D —Rhodamine WT dye G —coliphage J — indicator bacteria (standard bacterial plate count, total and fecal coliform) N —non-preserved (nitrite, phosphorus, BOD) O —on-site (pH, free and total chlorine, hardness) P —preserved (nitrate, ammonia, organic nitrogen, COD) T —total organic carbon (TOC) V — enteroviruses (3-day and 5-day)
	7-8	site	PL —Pleasanton
	9	sampling period	1 —Phase I 2 —Phase II, Pre-Fair 3 —Phase II, Post-Fair
	10-11		blank
	12-15	project number	4297

A numbering system was devised to identify each aerosol run. It is presented in Table D-30. D1-6 represents the sixth dye run conducted during Pre-Fair. M2-12 is the Post-Fair microbiological aerosol run whose samples were labeled run 12. Multiple run numbers were used on the sample labels of the quality assurance runs to provide blind portions, so that most quality assurance microbiological aerosol runs span several labeled run numbers, e.g. M1-27-30. The special enterovirus aerosol runs involved sequential 30-minute sampling periods, which were identified by numbers appended to the run number, e.g. V2-1.4 for the fourth sampling period of the first enterovirus run.

TABLE D-30
THE AEROSOL RUN NUMBER

Columns	Variable	Values and Interpretation
1	Type of aerosol run	D — dye aerosol run M — microbiological aerosol run V — special enterovirus aerosol run
2	Sampling period	1 — Pre-Fair, Phase II 2 — Post-Fair, Phase II
3	Hyphen	—
4-5	Run number(s) used on sample labels and run report data forms	1, 2, 3, ...

3. Aerosol Data Processing

In data analysis, the measured microbiological aerosol concentrations are presumed to accurately describe the microorganism levels emanating from the source under study (e.g., the line of sprayers). However, in a large-scale field program such as that conducted at Pleasanton, some measurements of microbiological aerosol concentrations are likely to reflect extraneous factors such as sampler/sample contamination or non-study sources that dominate the study source effect. In addition, the high variability of quantum microbiological measurements at levels close to the minimum detection limits of the methods used requires careful data smoothing techniques to avoid logical inconsistencies. The extraneous factors and variability-induced logical inconsistencies can have biasing and mathematically intractable consequences in data analyses such as the microbiological dispersion model development. Described in this section are the procedures that have been used to process the microbiological aerosol concentration data and to treat their undesirable characteristics.

a. *Standard Processing and Event Notation*

Several data conversions, corrections, and adjustments were made in determining the microbiological concentrations of the aerosol samples. The analysis laboratories reported their assayed aerosol sample results as the detected microorganism quantity per unit volume of BHI sampler fluid. These reported microorganism concentrations were converted to the microorganism quantity per cubic meter of air sampled. To facilitate this conversion, the final volume of the BHI sampler fluid was always made back up to 100 ml in the field after a run to replace fluid loss through evaporation during sampling. The other factor needed in the conversion, the corrected sampler air flow rate, is discussed below.

For Pre-Fair, the nominal sampler air flow rates of 1000 l/min (= 1.0 m^3/min) were corrected using the pinwheel anemometer results of a calibration test conducted shortly after the Pre-Fair sampling period (see Aerosol Sampling Methods in this appendix). The corrected air flow rates used were 1.00 m^3/min for sampler numbers 2 and 3; 1.09 m^3/min for sampler 8; 1.11 m^3/min for sampler 9; 1.13 m^3/min for samplers 1, 6, and 11; 1.21 m^3/min for sampler 10; 1.23 m^3/min for sampler 4; 1.28 m^3/min for sampler 5; and 1.30 m^3/min for sampler 7. During Post-Fair, the air flow rates were adjusted in the field before the run so that the actual air flow rate was maintained at 1000 l/min.

In the quality assurance aerosol run analysis for systematic sampler differences (Section VI.B.3), it is concluded that after correcting the air flow rates as above, there was no systematic bias in microbiological collection efficiency among the nine high-volume samplers evaluated. Thus, no microbiological collection efficiency correction factors were applied in developing the tabulated microbiological aerosol concentration data.

A system of foot notes was used to keep track of unusual events which might affect the measured concentration of an aerosol sample. These footnotes are listed in Figure VI.B-2.

The footnotes represent a compilation of the sampler operators' field notes on each run, the laboratory analysts' comments on unusual sample analyses and the statistician's overview assessment and data adjustments. Footnotes b, c, d, e, f, g, h, i, j, l, m, n, o, and q were derived from the sampler operator notes. Footnotes a, j, k, p, r, s, t, u, and v were obtained from the analysis laboratories' comments on the data reporting forms.

The aerosol sample concentrations with superscripted footnotes of c, d, e, and f have been adjusted to take the indicated field sampling problems into account. When extreme arcing of the high voltage was observed in a sampler (footnote c), the analytical result was adjusted upward by factors representing from 10% to 30% microbiological destruction; each arcing correction factor was estimated by comparative data analysis. When a sampler could not be operated for the entire 30-minute run sampling period (footnote d) the reported analysis value was adjusted upward by a factor inversely proportional to the fraction of time actually sampled. When a sampler experienced power supply problems (footnote e) or excessive loss of BHI sampler fluid from its container (footnote f), the reported value was adjusted upward by an appropriate factor estimated by the field supervisor.

It was often necessary to include occasional aerosol concentrations below the detection limit in the statistical analyses, to prevent an upward bias. In such cases, the value of one-fourth the detection limit was substituted for the "below detection limit" value when it was the only measurement at that distance. When there were several measurements at the distance, the "below detection limit" value was treated as a zero and a mean of the measurements was used as the aerosol concentration at that distance.

b. Sampler Contamination Inferences

Experience gained from air sampling both at Pleasanton and the Egan plant[90] showed that high-volume aerosol samplers are essential to obtain quantitative microbiological aerosol concentrations, especially for pathogens. However, the high-volume aerosol samplers have a tendency to become and remain contaminated with some of the hardy organisms, such as *Pseudomonas*, in parts that are unaffected by the extensive cleaning procedures routinely used. The primary evidence of sampler contamination is usually an extremely high standard bacterial plate count. Preliminary examination of the standard bacterial plate count aerosol data suggested that counts above 10,000/m^3 were presumptive of contamination. Comparison of the presumed contamination with the sampler number disclosed that, in many instances, the sampler was contaminated, did contaminate the sample, and remained contaminated over a series of runs. Special rigorous decontamination procedures were applied: disassembly of all samplers after runs M2-14 or M2-15; cleaning with alcohol (denatured ethanol) after QA runs M2-18-21. Subsequently, the alcohol cleaning procedure was occasionally used on some samplers. Since the analytical results were not available to the field crew until the next day, the sampler contamination problem was difficult to detect and correct in the field.

Because the large values associated with sampler contamination will dominate the statistical analysis, general criteria were developed for inferring sample contamination that has affected the analytical value, based on combined experience in Pleasanton and at the Egan plant. The values inferred to be affected by sampler contamination have been underlined in the tabulated aerosol concentration data. The ensuing statistical analyses were conducted excluding these underlined values.

Standard bacterial plate count values above 10,000/m^3 were considered contaminated, as were unusually high values from the same sampler on the preceding or following run. Sample contamination affecting the microorganism concentration result was also inferred by coupling (a) the likelihood of sample contamination from field and laboratory observations (see the footnotes), with (b) the extent the result deviated from the aerosol concentration pattern indicated by the results from the other samplers on the run. Sample contamination affecting the result was inferred, and indicated by underlining the aerosol concentration value, when any of the following conditions occurred:

(1) Certain sample contamination (footnotes n, o, p); or

(2a) Probable sample contamination (footnotes l, m) or corresponding standard bacterial plate count-inferred contaminated, and

(2b) the result was unusual (i.e., at least a factor of 5 from the pattern expected value); or

(3a) Possible sample contamination (footnotes g, h, i, j, k), and

(3b) the result was very unusual (i.e., at least a factor of 10 from the pattern expected value)

c. *Data Smoothing Procedures Applied in Microbiological Dispersion Model Development*

The standard joint estimation procedure for the microbiological dispersion model parameters (see Section VI. C.4.a) worked well when the downwind microbiological aerosol concentrations decreased with distance d from the spray line in a clear pattern for which even the most distant sampler's concentration exceeded the run background concentration. However, the aerosol run data tables (Appendix F) showed that the downwind concentrations for many microorganism groups on many runs were close to the lower concentration detection limits for most groups and to the upwind concentration for standard bacterial plate count. Thus the straightforward approach of using the sampled upwind concentration as the background concentration was unacceptable because in many cases concentration less background would have been zero, negative, or ill-defined (i.e., the difference of two "less than" values), so that the dependent variable y_d in equation (7) of Section VI. C.4 would have been undefined or very unreliable.

A better procedure was sought for estimating the general area background concentration for a microorganism group on a run. For the Post-Fair runs, a comparison was made of the upwind sampler concentration with the concentration of the far downwind sampler identified through the diffusion modeling as sampling the least aerosol from the spray irrigation line. Both the upwind and least-affected downwind concentrations of total coliform and coliphage were nearly always below the detection limit. For standard bacterial plate count and fecal streptococci, the upwind sampler concentration exceeded the least-affected downwind sampler concentration in over half of the runs that yielded valid comparisons (13 or 24 for standard bacterial plate count, and 10 of 17 for fecal streptococci). For mycobacteria, the least-affected downwind sampler was higher on 6 of the 7 runs compared, but this was not a significant increase using a one-sided sign test at the .05 significance level. Hence, it was decided that the least affected downwind sampler was as valid a measure of run background as was the upwind sampler on the Post-Fair runs.

When the microorganism concentration from the upwind sampler was correlated with the concentration from the least-affected downwind sampler over all the Post-Fair runs, very low correlations not significantly different from zero were obtained for all three frequently detected microorganism groups (r =

0.01 for standard bacterial plate count, $r = 0.31$ for fecal streptococci, and $r = 0.37$ for mycobacteria). This suggests that the concept of a constant diffused background concentration during a run for which the upwind sampler is representative is inadequate. The microorganism "background concentration" around a given sampler may be highly variable and due more to very localized microorganism sources than to the average diffusion from numerous distant sources. Consequently, it seems advisable to average the concentrations of as many as possible of the upwind and downwind samplers that can be identified as primarily sampling the "background" during the run when estimating the run background concentration. Since the background concentrations of most microorganism groups were generally near or below the individual sampler detection limits, an averaging process which involves several samplers can also greatly reduce either the uncertainty in estimating the "true mean" background or the combined detection limit for background.

The preceding considerations led to the following procedure for computing the background concentration of a microorganism group on a run. For all samplers designated as background (see below), the background for the model was computed as the geometric mean of the sampled concentrations when all were numerical (e.g., standard bacterial plate count); as the pooled concentration obtained from combining the BHI samples according to standard microbiological practice when some concentrations were below the detection limit; and as one-fourth the pooled detection limit when all concentrations were below the sampler detection limit. For microorganism groups on which the background was below the pooled detection limit on nearly all runs, a background of zero was used in place of one-fourth the pooled detection limit.

Downwind samplers were designated as background samplers if they were considered to be predominantly sampling the area background rather than the aerosol from the target spray line or another spray line. Designation as a background sampler for a microorganism group on a run involved consideration of the predicted spray line concentration reduction from the 50 meter downwind samplers to the farther downwind sampler due only to diffusion processes and of the observed microorganism concentration pattern with distance on the run. For the samplers at and beyond 100 meters downwind on a run, each sampler was ranked for background designation potential based on its diffusion model concentration relative to the diffusion model concentration D_{50d} for the 50-meter sampler:

Rank	Criterion	Background Designation Potential
x	wrong source	excluded from data analysis
b	$D < .05D_{50}$	background
b1	$.05D_{50} < D < .5D_{50}$, lowest such D	best background candidate
b2	$.05D_{50} < D < .5D_{50}$, second lowest such D	second best background candidate
b3	$.05D_{50} < D < .5D_{50}$, third lowest such D	third best background candidate
b?	$.5D_{50} < D < D_{50}$, lowest such D	only background candidate

The "only background candidate" potential designation was only applied to samplers on the Pre-Fair runs. The criterion $.05D_{50}$ was used because seldom (except for standard bacterial plate count) did the concentration C sampled at 50 meters exceed the detection limit by more than a factor of 20. Thus, if $D < .05D_{50}$, the spray line contribution at the distant sampler would be expected to be below the detection limit, especially taking microbiological viability decay into account. Hence, the background concentration might be expected to predominate in the sampled aerosol.

The rest of the background designation procedure was based on the sampled microorganism concentration pattern with distance on the run. If it yielded a high concentration value (at least an order of magnitude higher than the other definite and candidate background concentration values), an upwind sampler or b background sampler was excluded from the data analysis, because it was presumed to reflect a very localized background source. The best, second best, and third best background candidate samplers (b1, b2, and b3) were evaluated sequentially until one was refused background designation. A background candidate was accepted for background designation if any of the following criteria were satisfied:

- it was the least-affected downwind sampler and the upwind concentration was missing or excluded from data analysis;
- its microorganism concentration was less than or equal to the tentative background concentration based on the previously designated background samplers;
- at least half of the remaining background candidate samplers obtained concentrations less than or equal to the tentative background concentration.

An only background candidate sampler (b?) was accepted for background designation if its microorganism concentration was less than or equal to the upwind concentration.

After all of the background samplers for a microorganism group on a run were designated, the microorganism background concentration to be used for the run was computed by the appropriate averaging process, as described above.

Each of the remaining downwind samplers (not excluded from data analysis or designated as background) were usually treated as an observation of the model equation. These observations formed the pairs from which impact and decay factors were estimated by the simple linear regression model. There were several exceptions in forming downwind observations:

- if the microorganism concentration of one of a pair of samplers at the same distance d was below the detection limit or less than or equal to the background concentration, then the pooled concentration of the two samplers was used as the concentration for a single observation at that distance;
- if some microorganism concentrations were detectable and others were undetectable (or not greater than the background) for downwind adjacent samplers, then the pooled concentration of the samplers was used as the concentration for a single observation at the distance of the predominant detectable measurement;
- if an unusually high microorganism concentration was obtained relative to the concentration pattern for the run and the value was suspect according to its footnote, the observation was excluded from the data analysis for the footnoted reason;
- if a high microorganism concentration relative to the concentration pattern was obtained by a distant sampler (i.e., the distant sampler y value exceeded all the other downwind sampler y values for the run), the observation was excluded from the data analysis on the presumption it was caused by localized sources.

After computing the run background and the downwind sampler concentrations for a microorganism group by the preceding procedures, the suitability of each run set of observations was reviewed. Runs were excluded from the model development when the downwind concentrations tended to be less than the run background concentration (implying that the spray line microorganism source was undetectable), or when the concentration values were considered inadequate (e.g., all downwind and background concentrations below the detection limit, all measurements missing, or the preponderance of sample concentrations were inferred to be affected by contamination). The remaining run data sets were used in model development or model evaluation.

4. Computational Techniques

The automated computational techniques which were used to analyze the extensive data generated during this project were chosen as being the most appropriate from numerous options that were available. SwRI currently maintains a special lease arrangement with the McDonnell Douglas (McAuto) computer facility in Huntington Beach, California for use of their CDC Cyber 70/74 equipment. This system is accessed through a CDC remote batch terminal at the Institute's Computer Laboratory. In addition, a Hewlett Packard 9810A programmable calculator with a limited package of statistical routines was utilized when the desired analysis was less involved and the quantity of data was sufficiently small to permit direct keyboard entry. The major automated computational procedures used in this project are listed in Table V. E-1.

5. Statistical Approach

The specific objectives given in Section III. D. have been addressed by applying suitable statistical methods to the study data to make appropriate inferences (i.e. findings). Statistical analyses relevant to many of the objectives were performed upon obtaining the Pre-Fair data. In some cases, the Pre-Fair analysis provided adequate information and its methods and results are presented in Section VI. In other cases, a repeated analysis encompassing both the Pre-Fair and the Post-Fair data was performed and is reported in Section VI. The Pre-Fair data analyses suggested the propriety of developing the microbiological dispersion model. Development and evaluation of this model was the major emphasis of the Post-Fair data analysis.

TYPICAL CODED DATA REPORTING FORMS

Pre-Fair Data Reporting Forms

- Aerosol Run Report (Run 1)
- UTSA-CART Aerosol Run Analysis Report (Run 4)
- PEL Aerosol Run Analysis Report (Run 1)
- Dye Run Report (Run 3)
- UTSA-CART Wastewater Analysis Report (Samples 35, 36, 1LVMC, 2LVMC)
- PEL Wastewater Analysis Report (Sample 1)

Post-Fair Data Reporting Forms

- Post-Fair Aerosol Run Report (Run 29)
- Rotorad FP Analysis Report (Run 29)
- PIBAL Data Sheet (Run 29)
- UTSA-CART Aerosol Run Analysis Report (Run 36)
- PEL Aerosol Run Analysis Report (Run 4)
- Dye Run Report (Run 2)
- Spray Head Line Flow Rate Report (Run 2)
- UTSA-CART Wastewater Analysis Report (Runs 31, 32, 33, and 34)
- SwRI Wastewater On-Site Analysis Report (Runs 14-32)
- PEL Selective Analysis Report (Run 6)

Date Reported: 5/31/76

AEROSOL RUN REPORT

on Meteorology and Sampling Configuration
to David Camann on Project 01-4297

Aerosol Run Number 1

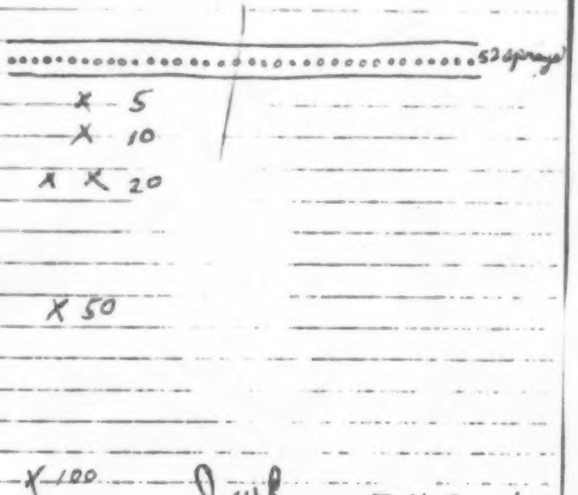
Run Date 5/4/76

SPRAYField B #1 setting
Dry Side of ~~Field~~ Sprayer Line NE dry
Left Sampler Line Position SE left

	Beginning of Sampling	End of Sampling
Time	1547	1617
Estimated Wind Angle, Θ	30	15
Estimated Pasquill Stability Class	A-B	A-B
Estimated Cloud Cover	2/8	3/8
Wind Velocity (at 10 m), mph		
Temperature (at 2 m), °F		
Relative Humidity (at 2 m), %		

Sampler Distance m.	High Volume Sampler Number
Upwind	1
5	4
10	5
20	2+3
50	6
100	7

Schematic of Sampler Configuration



COMMENTS:

Field Supervisor

UTSA-CAHT AEROSOL RUN ANALYSIS REPORT
to SwRI on Project 01-4297

1 of 2

Date
Reported ______

Run Number 4

Run Date and Time 5/13/76

Reports to: David Camann, San Antonio
James Register, Pleasanton

Wastewater Analysis:

SwRI Label Code GPΔE6PLZ

Corr. Coliphage Count 1.1×10^5 pfu/l

Raw Coliphage Count " pfu/l

Percent Efficiency N/A %

Aerosol Analysis:

Sampler	1	2	4	5
SwRI Label Code	1ΔAVPLZ	2ΔAVPLZ	4ΔAVPLZ	5ΔAVPLZ
Bacteria				
Klebsiella, cfu/100ml	BC	BC	BC	BC
Pseudomonas, cfu/100ml	<5 (ND)(10^3)	10×10^3	5.0×10^3	5.0×10^2
Streptococcus, cfu/100ml+	61×10^3	1.1×10^3	$>2.4 \times 10^3$	$\geq 2.4 \times 10^3$
Cl. perfringens, cfu/100ml+	<30 (ND)	<30 (ND)	<30 (ND)	<30 (ND)
Viruses				
3 Day Plaque Count, pfu/ml	~~0.08~~*	<0.08 (ND)	<0.08 (ND)	<0.08 (ND)
5 Day Plaque Count, pfu/ml	~~0.08~~*	<0.08 (ND)	<0.08 (ND)	~~0.08~~*
Coliphage				
Coliphage Count, pfu/ml	0.04	<0.04 (ND)	<0.04 (ND)	<0.04 (ND)

COMMENTS:

BC - Biochemical Confirmation underway
+ MPN
* Possible viral isolate - to be confirmed <0.08 (ND)

NOTATION:
TNTC-too numerous to count
ND-none detected
CS-contaminated sample

Continuation of 2 of 2

UTSA-CART AEROSOL RUN ANALYSIS REPORT
to SwRI on Project 01-4297

Run No. 4

Aerosol Analyses:				
Sampler	6	7		
SwRI Label Code	64AVPLZ	7ΔAVPLZ		
Bacteria				
Klebsiella, cfu/100ml	BC	BC		
Psuedomonas, cfu/100ml	CS	20×10³		
Streptococcus, cfu/100ml+	≥2.4×10³	≥24×10³		
Cl. perfringens, cfu/100ml+	<30 (ND)	90		
Viruses				
3 Day Plaque Count, pfu/ml	<0.08(ND)	<0.08(ND)		
5 Day Plaque Count, pfu/ml	<0.08(ND)	<0.08(ND)		
Coliphage				
Coliphage Count, pfu/ml	0.04	<0.09 (ND)		

COMMENTS:

+MPN

NOTATION: TNTC-too numerous to count
ND-none detected
CS-contaminated sample

PACIFIC ENVIRONMENTAL LABORATORY

AEROSOL RUN ANALYSIS REPORT
to SwRI on Project 01-4297

Received 5/5/76
Reported 5/18/76

Run No. 1
Run Date and Time ________ ________

Reports to: Richard Thomas, San Antonio
James Register, Pleasanton

Wastewater (GRAB) Analyses:

SwRI Code GPIEJPL2

PEL No. 762042

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Standard Plate Count No./100ml
1,500,000	150,000	1.0×10^8
1,600,000	140,000	1.0×10^8
1,410,000	160,000	1.2×10^8
1,200,000		
1,700,000		

AEROSOL Analyses:

SAMPLER 1
SwRI Code 11AJPL2
PEL No. 762043

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Standard Plate Count No./100ml
<200	<33	190000
		120,000

SAMPLER 2
SwRI Code 21AJPL2
PEL No. 762044

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Standard Plate Count No./100ml
<200	<33	20000
		30000

COMMENTS:

NH TN Analyst
T. Director
for R. A. Ryder

PACIFIC ENVIRONMENTAL LABORATORY

Continuation of AEROSOL RUN ANALYSIS REPORT Run No. 1

AEROSOL Analyses:

SAMPLER 3

SwRI Code 31AJPL2

PEL No. 762045

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Standard Plate Count No/100ml
<200	<33	1100000
		1,300,000

SAMPLER 4

SwRI Code 41AJPL2

PEL No. 762046

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Total Plate Count No./100ml
200	67	350000
400		390,000

SAMPLER 5

SwRI Code 51AJPL2

PEL No. 762047

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Standard Plate Count No./100ml
200	<33	49000
400		58,000

SAMPLER 6

SwRI Code 61AJPL2

PEL No. 762048

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Total Plate Count No./100ml
<200	<33	3000
		4000

SAMPLER 7

SwRI Code 71AJPL2

PEL No. 762049

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Standard Plate Count No./100ml
<200	<33	5000
		6000

SAMPLER

SwRI Code

PEL No.

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Total Plate Count No./100ml

COMMENTS:

NH, TN Analyst

for Director

DYE RUN REPORT

on Meteorology, Sampling Configuration, and Dye Analyses
to David Camann on Project 01-4297

Date Reported: 6/15/76

Dye Run Number 3

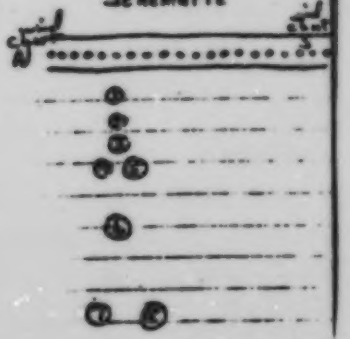
Run Date May 28, 1976

Field 2
Side of Field East (Dry)
Sampler Line Position 45
Left

	Beginning of Sampling	End of Sampling	
Time	1555	1625	
Estimated Wind Angle, θ	45	45	45°
Estimated Pasquill Stability Class	B	B	
Estimated Cloud Cover	clr	clr	
Wind Velocity (at 10 m.), mph			
Temperature (at 2 m.), °F			
Relative Humidity (at 2 m.), %			

Sampler Distance m.	AGI Sampler Number	Analyzed Dye Concentration ppb	µg total	Sampled Dye Concentration µg/m³
5	1	11.0	1.1	1.294
10	2	15.5	1.55	1.824
15	3	22.2	2.22	2.613
20	4	14.5	1.45	1.707
20	5	16.5	1.65	1.942
50	6	14.0	1.40	1.648
100	7	15.0	1.50	1.765
100	8	14.5	1.45	1.707

Sampler Configuration Schematic



Wastewater Sample 96,000 before — 54,000 µg/l after

COMMENTS: 30 cft × 2.832×10⁻² m³/cft = .8496 m³

$\frac{\mu g}{2.832 \times 10^{-2} \times \text{cft}} = \frac{\mu g}{m^3}$

J. Harding Analyst

Field Supervisor

UTSA-CART WASTEWATER ANALYSIS REPORT
to SwRI on Project 01-4297

Date
Reported

Reports to: David Camann, San Antonio
James Register, Pleasanton

Sample Number	35	36	1LVMC	2LVMC
Bacteria				
SwRI Label Code	Q35EBPL2	Q36EBPL2	1LVMC	2LVMC
Klebsiella, cfu/100ml	BC	BC	CS	CS
Pseudomonas, cfu/100ml	5.0×10^4	2.5×10^4	CS	3.0×10^5
Streptococcus, cfu/100ml@	1.1×10^4	CS	CS	CS
Cl. Perfringens, cfu/100ml$	2.4×10^2	2.4×10^2	CS	1.1×10^4
Viruses				
SwRI Label Code	Q35EVPL2	Q36EVPL2	1LVMC	2LVMC
3 Day Plaques				
Corrected Count, pfu/l	0	4.7	244	40
Raw Count, pfu/l	0	3.7	110	40
Percent Efficiency,%	31%	79%	45%	100%
5 Day Plaques				
Corrected Count, pfu/l	4.7	9.8	262	28
Raw Count, pfu/l	2.9	7.8	118	28
Percent Efficiency,%	31%	79%	45%	100%
Coliphage				
SwRI Label Code	Q35EGPL2	Q36EGPL2	1LVMC	2LVMC
Corrected Count, pfu/l	9.7×10^4	1.0×10^5	2.1×10^5	5.0×10^5
Raw Count, pfu/l	-	-	8.6×10^4	-
Percent Efficiency,%	N/A	N/A	41%	N/A

COMMENTS:

@ BC- Biochemical Confirmation under way
$ MPN

NOTATION: TNTC-too numerous to count
ND-none detected
[illegible]

PEL **WASTEWATER ANALYSIS REPORT**
to SwRI on Project 01-4297

Reported 5/18/76

Sample No. 1
Date Sampled: ________

Reports to: Richard Thomas, San Antonio
James Register, Pleasanton

Routine Analyses:

COLI Bottle

SwRI Code CRIEJPL2

PEL No. 762019

Total Coliform MFC/100ml	Fecal Coliform MFC/100ml	Standard Plate Count No./100ml
1,800,000	120,000	1.4×10^8
1,400,000	110,000	1.2×10^8
1,900,000	120,000	1.4×10^8

SOLIDS Bottle

SwRI Code CRIESPL2

PEL No. 762019

Total Suspended Solids mg/1	Total Solids mg/1
48	634
50	610

Selective Analyses:

NON-PRESER Bottle

SwRI Code CRIENPL2

PEL No. 762019

B.O.D.$_5$ mg/1	Nitrite Nitrogen mg/1	Total Phosphorus mg/1
26	0.06	6.4
26	0.07	6.7
24	0.06	6.5
		6.5
		6.5

PRESERVED Bottle

SwRI Code CRIEPPL2

PEL No. 762019

C.O.D. mg/1	Nitrate Nitrogen mg/1	Ammonia Nitrogen mg/1	Organic Nitrogen mg/1
138	0.03	24.64	5.88
	0.04	25.76	6.72
	0.03	25.20	
	0.03		
	0.03		

COMMENTS:

NH.TN **Analyst**

for **Director**
R. A. Ryder

POST-FAIR AEROSOL RUN REPORT

Date Mailed: Rc'd 4-18

to: David Carver, S.A. (copy)
R. Keith Dumbauld, Carver (orig.)
Project C1-4297

Aerosol Run Number 29

Run Date April 11, 1977
Field B Setting 7
Run Times 1515 to 1545
Side of Spray Line Dry

Five Min. Mean Wind Angles τ and φ

	4m - met tower τ	4m - met tower φ	2m - field φ
Begin sampler set-up	250	-30	
Just prior to run	258	-38	55
Run: 0 - 5 min.	259	-39	50
5 - 10 min	248	-25	
10 - 15 min	258	-38	
15 - 20 min	258	-38	50
20 - 25 min	276	-56	
25 - 30 min	274	-54	

Protocol Decisions

Close sampler position Left
Distant sampler lines H, B, K
Separation 300 m
Near rotorod lines M, A

Critical Wind Angles φ

Initiate: α = -54 to β = -6
Good: γ = -63 to δ = 21
Samples Shipped? Yes
Samples Analyzed? Yes

Spray Heads

	Number	Covered Heads		
Left Side	26	None		
Right Side	27	None		

Distance from spray line to wet line edge 12 m
Effluent temperature 19.8 °C

High Volume Samplers

Sampler Locations Distance	Sampler Locations Position	Sampler Number
Upwind	[illegible]	1 (1)
50m, left		2 (19)
50m, right		3 (Alt 3)
100m, left		4 (4)
100m, right		5 (Alt)
[illegible] right	H2	6 (3)
[illegible] center	H9	7 (17)
[illegible] left	B5	9 (16)

Meteorological Conditions During Run

4m level at met Tower:
Mean wind velocity 3.5 m/sec
Temperature 71.3 °F, 21.7 °C
Dew point 39.4 °F, 3.9 °C
Relative humidity 29 %
Temp dif ΔT (32m - 4m) -3.2 °F

Just outside wetted area:	(Upwind)	(Downwind)
Temperature	71.5 °F	70 °F
Relative humidity	31 %	38 %

Ave. solar radiation 0.98 g cal/cm²
Cloud cover <¼ Min cloud height N.A.

COMMENTS/PROTOCOL DEVIATIONS:

Rev. Jan 13, 1977

[illegible] MSH Field Supervisor

2

Date Mailed: ____

ROTOROD FP ANALYSIS REPORT

to: David Cammer, S.A. (copy)
R. Keith Dumbauld, Clower (orig)

Aerosol Run Number 29

Run Date 4-11-77
Run Times 1615 to 1645

Field B Setting 7
Side of Spray Line dry

Rotorod Sampler Data

	Stake Location	FP Level Code
Background		
Near Line	M5	2
	M6	4
	M7	2
	M8	3
	A1	2
	A2	1
	A3	1
	A4	1
	A5	1
	A6	1
Distant Line	H2	2
	H4	2
	H6	3
	H8	1
	B2	1
	B5	1
	B7	1
	B9	1
	K9	2
	K11	1

FP Level Key

Level Code	FP Level Interpretation
1	Negative
2	Very light
3	Light
4	Medium
5	Heavy
6	Very heavy

COMMENTS:

Batteries on M6
& A1 went dead
during run

Carol Marsh FP Analyst

____ Field Supervisor

PIBAL DATA SHEET

DATE 4-11-77

TIME 1516

OBSERVER [illegible] Salinas

FREE Lift (Grams) 30g

LOCATION MET TOWER Pleasanton

TEST NR [illegible] #29 -2

MIN	ELEVATION	AZIMUTH	HEIGHT(m)	HORIZ. DIST.	DIRECTION	SPEED(m/sec)	SPEED(MPH)
30							
1	48.9	222.9	216	190	300	2.5	
30							
2	53.0	300.5	414	310	335.5	2.8	
30							
3	55.5	315.1	612	420	13.9	2.6	
30							
4	57.9	335.0	801	500	19.2	3.9	
30							
5	54.2	344.1	990	715	13.4	5.0	
30							
6	48.5	356.2	1170	1035	2.2	5.9	
30							
7	43.4	355.5	1350	1432	350	6.2	
30							
8	40.6	353.2	1530	1785	344.8	6.3	
30							
9	38.4	351.8	1710	2160	348	9.0	
30							
10	33.4	351.5	1890	2865	350.2	12.0	
30							
11							
30							
12							
30							
13							
30							
14							
30							
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18							
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19							
30							
20							
30							
21							
30							
22							

UTSA-CART AEROSOL RUN ANALYSIS REPORT
to SwRI on Project 01-4297

1 of 2

Date Reported 4/29/77

Run Number 36

Run Date 4/13/77

Reports to: David Camann, San Antonio
Mike Taylor, Pleasanton

Aerosol Analysis:

Sampler	1	2	3	4
SwRI Label Code	1 36AUPL3	2 36AUPL3	3 36AUPL3	4 36AUPL3
Coliphage				
Coliphage Count, pfu/ml	<0.04(ND)	0.12	0.04	0.08
Bacteria				
Fecal Streptococci, cfu/100ml	10	10	10	3.3
Mycobacteria, cfu/100ml	<10 (ND)	50	20	30

Other Bacteria

Type	Units				

COMMENTS:

NOTATION: TNTC - too numerous to count
ND - none detected
CS - contaminated sample

Sorber Lab Director

Rev. Jan. 1977

UTSA-CART AEROSOL RUN ANALYSIS REPORT
to SwRI on Project 01-4297

2 of 2

Date Reported 4/29/77

Run Number 36

Run Date 4/23/77

Reports to: David Camann, San Antonio
Mike Taylor, Pleasanton

Aerosol Analysis:

Sampler	5	6	7	8
SwRI Label Code	5 36AVPL3	6 36AVPL3	7 36AVPL3	8 36AVPL3
Coliphage				
Coliphage Count, pfu/ml	0.04	<0.04(ND)	<0.04(ND)	<0.04(ND)
Bacteria				
Fecal Streptococci, cfu/100ml	<3.3(ND)	50	3.3	3.3
Mycobacteria, cfu/100ml	30	<10 (ND)	<10(ND)	30

Other Bacteria

Type	**Units**				

COMMENTS:

NOTATION: TNTC - too numerous to count
ND - none detected
CS - contaminated sample

Sorber **Lab Director**

Rev. Jan. 1977

PACIFIC ENVIRONMENTAL LABORATORY 1 of 2

AEROSOL RUN ANALYSIS REPORT
to SwRI on Project 01-4297

Received 1/31/77
Reported 2/11/77

Run No. 4
Run Date

Reports to: Dave Camann, San Antonio
Mike Taylor, Pleasanton
Richard Thomas, San Antonio

Wastewater (Composite) Analyses:

SOLIDS (S) BOTTLE

SwRI Code [illegible]
PEL No. 77452

Total Suspended Solids (mg/l)
13
15

COLI (J) BOTTLE

SwRI Code [illegible]
PEL No. 77453

Total Coliform MFC/100ml	Standard Plate Count No. /100 ml
250,000	25x10^6
[illegible]	21x10^6
240,000	26x10^6
250,000	27x10^6

AEROSOL ANALYSES

SAMPLER 1
SwRI Code [illegible]
PEL No. 77458

Total Coliform MFC/100ml	Standard Plate Count No. /100ml
<7	23,000
	22,000

SAMPLER 2
SwRI Code [illegible]
PEL No. 77455

Total Coliform MFC/100ml	Standard Plate Count No. /100ml
190	16,000
200	15,000
	14,000
	16,000

COMMENTS:

NH, TN Analyst

for Director
R. A. Ryder

Rev. Jan. 1977

PACIFIC ENVIRONMENTAL LABORATORY 2 of 2

Continuation of AEROSOL RUN ANALYSIS REPORT Run No. 4

AEROSOL Analyses:

SAMPLER 2		SAMPLER 4		SAMPLER 5	
SwRI Code 24APR[illegible]291		SwRI Code 44APR[illegible]297		SwRI Code 54APR[illegible]	
PEL No. 77456		PEL No. 77457		PEL No. 77458	
Total Coliform MFC/100ml	Standard Plate Count No. /100ml	Total Coliform MFC/100ml	Standard Plate Count No. /100ml	Total Coliform MFC/100ml	Standard Plate Count No. /100ml
200	56,000	60	5,000	30	12,000
150	52,000		4,200		14,000

SAMPLER 6		SAMPLER 7		SAMPLER 8	
SwRI Code 64A[illegible]297		SwRI Code 74APR3A297		SwRI Code 84APR[illegible]297	
PEL No. 77459		PEL No. 77460		PEL No. 77461	
Total Coliform MFC/100ml	Standard Plate Count No. /100ml	Total Coliform MFC/100ml	Standard Plate Count No. /100ml	Total Coliform MFC/100ml	Standard Plate Count No. /100ml
<6	16,000	<6	29,000	<6	70,000
	18,000		20,000		77,000
	17,000				

COMMENTS:

Rev. Jan. 1977

NH TN Analyst

for T. Nakamura
R. A. Ryder Director

DYE RUN REPORT

Date Reported: ____

to: David Camann, S.A.
R. Keith Dumbauld, Cramer
Project 01-4297

Dye Run Number 2

Run Date December 5, 1976
Field D
Setting 6
Heads 52
Run Times 1253 to 1323
Side of Field WET

Mean Wind Angle ϕ

Station (4m)		100m (2m)	
Prior	20	Prior	0
0-5	20		
5-10	0	0-15	0
10-15	0		
15-20	-5		
20-25	0	15-30	0
25-30	0		

Spray Head Flow Rates 1 3 5
(Sec. to fill 20l.)
Left side SEE Flow Velume
Right side For Day

Covered Spray Heads
Left side None
Right side None

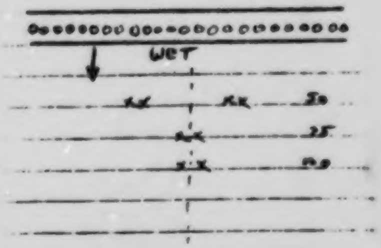
Distance from wet line edge to spray line 13.5 m
Effluent temperature 16 °C

Met. Conditions at 4 m Sensor
Wind velocity 10 mph
Rel. humidity SEE Below %
Dew Point 25°
Temperature 68 °F
ΔT (32m - 4m) SEE Above °F

Cloud cover 1/8
Minimum cloud height High

Sampler Distance m	AGI Sampler Number	Analyzed Dye Conc. ppb	Trapped Dye µg	Sampled Dye Conc. µg/m³ ÷ (0.8496)
50 m	1	5.7	0.57	0.67
50 m	2	5.9	0.59	0.69
50 m	3	5.3	0.53	0.62
50 m	4	4.9	0.49	0.58
75 m	5	3.5	0.35	0.41
75 m	6	4.0	0.40	0.47
100 m	7	2.9	0.29	0.34
100 m	8	3.3	0.33	0.39

Sampler Configuration Schematic



Effluent Grab Samples: Before 21,900 µg/l
After 20,600 µg/l

COMMENTS: Humidity, Temp Upwind 26% 65°F
in Spray Line: 55% 58°F

CM Analyst
Field Supervisor

SPRAY HEAD LINE FLOW RATE REPORT

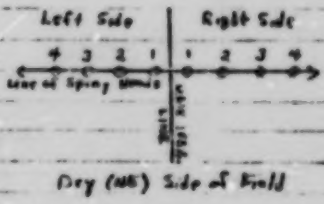
Field D
Setting 6

Date Measured 12/5/76
Time Measured 1335 to 1420

to: David Cowan, S.A.
R. Keith Dowbould, Cro
Project a-4297

Spray Head Number	Left Side Spray Heads Sec. to fill ~~20ℓ~~ 20.6	ℓ/min	Comments	Right Side Spray Heads Sec. to fill ~~20ℓ~~ 20.6	ℓ/min	Comments
1	11.0	112.4		12.6	98.1	
2	16.6	74.5		11.3	109.4	
3	13.2	93.6		13.5	91.6	
4	13.0	95.1		18.2	67.9	
5	15.0	82.4		15.5	79.7	
6	15.4	80.3	off about 30°	15.8	78.2	
7	16.0	77.3		15.2	81.3	
8	19.4	63.7		17.0	72.7	
9	17.8	69.4		17.4	71.0	
10	19.6	63.0		19.7	62.7	
11	19.2	64.4		18.2	67.9	
12	19.0	65.0		21.2	58.3	
13	34.4	35.9		20.8	59.4	
14	19.2	64.4		20.0	61.8	
15	24.5	50.6		22.9	53.9	
16	23.1	53.5		40.1	30.8	
17	24.2	51.1		22.6.	54.7	
18	23.5	52.6		24.4	50.6	~30° off [illegible]
19	22.0	56.2		23.2	53.3	
20	23.9	51.7		25.6	48.3	
21	24.9	49.6	~15-20° [illegible]	24.8	49.8	
22	24.0	51.5		23.9	51.7	
23	22.0	56.2		23.0	53.7	
24	22.8	54.2		28.1	43.9	
25	33.2	37.2		25.8	47.9	
26	34.2	36.1		27.5	44.9	
27						

Note: The left and right sides of the main irrigation line are determined when facing the spray head line from the dry (NE) side of the field.



COMMENTS:

Spray line to wet line 13.5m.

Field Supervisor

UTSA - CART WASTEWATER ANALYSIS REPORT
to SwRI on Project 01-4297

Date Reported 4/[illegible]/77

Reports to: David Camann, San Antonio
Mike Taylor, Pleasanton
Richard Thomas, San Antonio

Run Number	31	32	33	34
Total Organic Carbon				
SwRI Label Code	31ETR3	32ETR3	33ETR3	34ETR3
Analyses for Total Organic Carbon (TOC), mg/l	12	17	34	34
Coliphage				
SwRI Label Code	31EGR3	32EGR3	33EGR3	34EGR3
Corrected Count, pfu/l	2.4×10^5	2.4×10^5	4.5×10^5	2.0×10^5
Raw Count, pfu/l	2.4×10^5	2.4×10^5	4.5×10^5	2.0×10^5
Percent Efficiency, %	N/A	N/A	N/A	N/A
Bacteria				
SwRI Label Code	31EGR3	32EGR3	33EGR3	34EGR3
Fecal Streptococci, cfu/100ml	6.2×10^3	3.6×10^3	2.2×10^3	1.9×10^3
Mycobacteria, cfu/100ml	5.6×10^3	7.6×10^3	7.5×10^3	7.6×10^3

Other Bacteria

Type	Units				

COMMENTS:

Sorber Lab Director

NOTATION: TNTC - too numerous to count
ND - none detected
CS - contaminated sample

Rev. Jan. 1977

SwRI WASTEWATER ON-SITE ANALYSIS REPORT
Project 01-4297

Date Mailed R'd 4-19

Reports to: David Camann, San Antonio (copy)
Richard Thomas, San Antonio (orig.)

Date	Run Number	pH	Conductivity µ mho/cm
~~3/11/77~~	~~[illegible]~~	~~8.45~~	~~1425~~ ABORTED
3/14/77	14	8.65	1425
3/16/77	15	8.6	1390
3/17/77	16	8.6	1310
3/18/77	17	8.5	1425
3/22/77	18-21(6A#2)	8.5	1510
3/25/77	22	8.5	1400
3/26/77	23	8.42	1390
3/26/77	24	8.56	1400
3/27/77	25	8.5	1450
3/27/77	26	8.55	1375
4/11/77	29	8.5	1325
4/12/77	30	8.5	1375
4/13/77	31	8.5	1375
4/14/77	32	8.5	1390

COMMENTS:

Rev. Jan. 1977

____________________ Analyst

PACIFIC ENVIRONMENTAL LABORATORY

SELECTIVE ANALYSIS REPORT
to SwRI on Project 01-4297

Received 2/10/77
Reported 3/7/77

Run No. 6
Run Date

Reports to: David Camann, San Antonio
Mike Taylor, Pleasanton
Richard Thomas, San Antonio

PRESERVED (P) BOTTLE

SwRI Code CS6EPRL34297

PEL No. 77642

COD mg/l	Nitrate Nitrogen mg/l	Ammonia Nitrogen mg/l	Crganic Nitrogen mg/l
72	0.19	32.6	4.1
68	0.20		4.4

NON-PRESERVED (N) BOTTLE

SwRI Code CS6ENPL34297

PEL No. 77642

BOD_5 mg/l	Nitrite Nitrogen mg/l	Total Phosphorus mg/l
8.5	0.04	5.0
8.5	0.04	

SOLIDS (S) BOTTLE

SwRI Code CR6ESPL34297

PEL No. 77642

Total Solids mg/l
662

COMMENTS:

NH, TN Analyst

Director

for R. A. Ryder

Rev. Jan '77

APPENDIX E
PHYSICAL AND CHEMICAL DATA ON WASTEWATER AND PATTERNS OBSERVED

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APPENDIX E
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A. Wastewater Characteristics

1. Chemical Data and Patterns

a. *Chemical Data*

In both Pre- and Post-Fair, daily composite samples were taken of the effluent for chemical analysis. Chemical analyses were conducted, according to routine and selective protocols. Analyses conducted on each daily composite sample are defined as routine and other analyses, conducted on a less frequent basis, are defined as selective. In the Pre-Fair sampling period, selective analyses were conducted on approximately one-half of the samples, and in the Post-Fair period the selective analyses were conducted on three samples. In Pre-Fair, each daily composite sample was analyzed for total and free chlorine, pH, TOC, total solids, and total suspended solids (TSS). The data obtained from the routine analyses are contained in Table IV.E-1. The selective analyses during Pre-Fair were BOD, COD, total phosphorus, hardness, and nitrite, nitrate, ammonia, and organic nitrogen. Selective analyses were made on alternate samples during Pre-Fair.

The daily composite samples were analyzed on-site for total and free chlorine and pH. Most of the samples were sent to SwRI for TOC analysis and to PEL for total solids and TSS. The results of these analyses are shown in Table E-1. The on-site analyses are based on a single determination. The TOC values are the average of a minimum of five repetitions, and total solids and TSS the average of duplicate determinations.

All the chlorine analyses were below the detection limits of the method: 0.1 mg/l for total and 0.05 mg/l for free chlorine. This was expected, since the chlorine is added to the wastewater only as an odor-controller and at very low levels. The pH varied from 8.2 to 8.7 over the sampling period. For the TOC, most of the reported values were obtained by SwRI. However, there were two values obtained by EQA on samples that were not run by SwRI. In addition, five values obtained were the result of apparent contamination of the sample, and were not used in any further analyses. The total and suspended solids give an indication of the quality of the effluent over the period. The skewness and kurtosis values indicate that all of the parameters except total solids follow a symmetric distribution, and as a result, the arithmetic mean and standard deviation are used to summarize these results. Total solids follow a normal distribution when logarithmically transformed, and thus the geometric mean and standard deviation are used to describe these data.

The results of the selective analyses for Pre-Fair are shown in Table E-2, and TOC values for these runs are shown for comparison. The COD values are generally the average of duplicate determinations, BOD the average of triplicates and hardness the result of a single determination. Total phosphorus and all nitrogen analyses were run in at least duplicate and often triplicate analyses. Of all selective analyses, only one value, that for the nitrate nitrogen analysis of sample 33, fell below the detection limit of 0.02 mg/l. All data are summarized for the sampling period by their arithmetic means and standard deviations.

For the Post-Fair study, routine measurements were made for TOC, pH, conductivity, and TSS. Analyses for total and free chlorine were not conducted based upon the results of the Pre-Fair study,

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Table E-1
ROUTINE CHEMICAL ANALYSIS OF DAILY COMPOSITES

Sample No.	Date	Total Chlorine (mg/l)*	Free Chlorine (mg/l)†	pH	TOC (mg/l)	Total Solids (mg/l)	TSS (mg/l)
1-2	5-2	ND	ND	8.3	25	622.0	49.0
2	3	ND	ND	8.5	23‡	612.0	60.0
3	4	ND	ND	8.2	59	597.0	46.0
4	5	ND	ND	8.6	48	588.0	43.0
5**	7	ND	ND	8.5	38	606.0	29.0
32**	8	ND	ND	8.5	47	593.0	47.0
33**	9	ND	ND	8.4	126††	588.0	33.0
34**	10	ND	ND	8.5	296††	608.0	43.0
35**	11	ND	ND	8.3	98††	656.0	64.0
36	11	ND	ND	8.5	26	629.5	48.0
37	12	ND	ND	8.6	47	646.5	62.0
98	13	ND	ND	8.4	119††	611.0	64.0
71	14	ND	ND	8.2	50	697.0	72.0
1-3	15	ND	ND	8.4	48	619.5	54.0
61	16	ND	ND	8.2	48	640.0	64.0
70	17	ND	ND	8.2	49	653.5	59.0
41	18	ND	ND	8.3	41	598.5	53.0
76	19	ND	ND	8.4	39	664.0	46.0
67	20	ND	ND	8.4	38	644.5	36.0
38	21	ND	ND	8.4	39	675.5	46.0
75	22	ND	ND	8.2	37	651.5	52.0
64	23	ND	ND	8.2	37	623.0	44.0
39	24	ND	ND	8.2	32	586.0	32.0
62	25	ND	ND	8.4	20‡	612.0	32.0
99	26	ND	ND	8.3	29	606.0	14.5
74	27	ND	ND	8.2	23	618.0	11.5
63	28	ND	ND	8.2	23	643.0	9.5
40	29	ND	ND	8.4	24	613.5	9.5
97	30	ND	ND	8.2	24	587.0	7.0
60	31	ND	ND	8.3	29	597.0	6.0
73	6-1	ND	ND	8.3	23	587.0	11.0
42	2	ND	ND	8.2	29	593.0	9.5
69	3	ND	ND	8.4	32	61[illegible].0	15.0
66	4	ND	ND	8.4	28	593.[illegible]	16.0
95	5	ND	ND	8.4	28	659.5	21.0
68	6	ND	ND	8.7	29	659.5	18.0
77	7	ND	ND	8.7	101††	651.0	13.0
72	8	ND	ND	8.6	29	658.5	16.0
65	9	ND	ND	8.6	24	712.0	13.5
96	10	ND	ND	8.7	32	681.5	14.0
43	11	ND	ND	8.6	27	671.5	8.5
78	12	ND	ND	8.6	25	697.0	9.5
50	13	ND	ND	8.6	26	690.0	20.5
51	14	ND	ND	8.7	20	685.0	15.0
52	15	ND	ND	8.7	26	780.0	55.0
53	16	ND	ND	8.7	26	757.0	41.0
56	17	ND	ND	8.7	24	719.5	39.0
58	22	ND	ND	8.5	23	672.5	14.0
Mean		–	–	8.43	33.0	639.06	33.0
Std Dev		–	–	0.17	9.9	45.73	20.0
CV, %		–	–	2.0	30.0	7.2	60.6

*Detection limit 0.1 mg/l.

†Detection limit 0.05 mg/l.

‡Analysis performed by EQA.

**Composite sampler inoperative, grab sample taken morning following spraying.

††Probable contamination.

Table E-2
SELECTIVE CHEMICAL ANALYSES OF DAILY COMPOSITES (mg/1)

Sample No.	Date	TOC	BOD	COD	Total Phosphorus	Hardness	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia Nitrogen	Organic Nitrogen
1	5-2	25	25.3	138	6.5	220	0.06	0.03	25.20	6.30
3	4	59	25.3	138	7.1	210	0.07	0.03	22.59	8.35
5*	7	38	14.7	109	6.3	190	0.05	0.03	25.48	6.44
33*	9	126†	19.0	92	6.1	215	0.07	ND‡	25.42	5.74
35*	11	98†	22.6	103	6.5	210	0.11	0.03	25.42	7.00
37	12	47	20.8	135	7.8	195	0.11	0.03	23.24	6.72
71	14	50	27.2	135	5.9	215	0.12	0.085	21.84	7.14
61	16	48	16.7	147	6.0	220	0.11	0.03	23.80	7.56
41	18	41	24.6	136	5.35	220	0.12	0.05	26.88	6.02
67	20	38	21.7	101	4.6	230	0.19	0.07	24.36	5.60
75	22	37	21.0	109	4.4	225	0.21	0.05	23.24	5.46
39	24	32	17.0	95	4.1	240	0.20	0.07	26.04	4.62
99	26	29	15.3	83	5.1	230	0.18	0.07	24.36	3.08
63	28	23	10.5	77	4.9	230	0.175	0.085	24.92	2.66
97	30	24	12.0	70	4.5	240	0.16	0.04	25.39	1.49
73	6-1	23	15.7	81	6.1	245	0.195	0.05	28.84	2.52
69	3	32	16.7	99	6.5	230	0.235	0.085	25.76	4.62
95	5	28	19.0	82	5.0	225	0.255	0.05	24.64	5.04
77	7	101†	16.3	87	5.35	275	0.20	0.047	25.48	4.76
65	9	24	11.5	75	5.5	255	0.17	0.075	22.21	4.39
43	11	27	21.7	86	5.5	255	0.10	0.13	22.77	5.98
50	13	26	17.5	84	5.0	260	0.225	0.07	22.96	7.56
52	15	26	20.5	71	5.0	245	0.157	0.055	19.60	5.60
56	17	24	17.0	79	4.8	280	0.223	0.08	14.56	8.12
58	22	23	17.5	75	5.5	235	0.08	0.04	22.40	6.02
	Mean	–	18.68	99.49	5.58	235.2	0.151	0.055	23.896	5.552
	Std Dev	–	4.39	24.70	0.90	21.1	0.061	0.027	2.713	1.763
	CV %	–	23.5	24.8	16.1	9.0	40.2	49.1	11.4	31.8

*Composite sampler inoperative, grab samples taken morning after spraying.

†Probable contamination.

‡Detection limit, 0.02 mg/l.

which indicated that no detectable level could be expected. Only three water samples were sent for selective analyses during the study period for analyses of the nitrogen series, total phosphorus, BOD, COD, and total solids. These data are summarized in Table E-3 for the routine and in Table E-4 for the selective analyses.

There was little variation in the pH of the effluent, with a range of 8.2 to 8.7 and a standard deviation of 0.1. There was more variation within the other parameters, however. For TOC, the values ranged from a low of 11 mg/l to a high of 41 mg/l, excluding the value for run 6. This sample was received at an elevated temperature and the result is not considered valid.

The range of TSS was from 5 to 95 mg/l, and for conductivity, from 1290 to 1590 mho/cm. For both of these and for TOC, a consistent tendency is noted where the effluent was of lower quality during the final week of the Post-Fair sampling. In fact, these three parameters show a good relationship over the entire sampling period, tending to rise and fall together.

The selective analyses give some indication of the levels of these chemical and physical constituents over the sampling period. Runs 2 and 6 are similar to the higher quality of the effluent during the early portion of Pre-Fair, while Run 25 was above the mean for TOC, TSS, and conductivity measurements. A similar pattern can be seen among the routine measurements.

b. *Distributional Characteristics*

The results of the chemical analyses during Pre-Fair were tested for the normality of their distribution. This was accomplished by calculating coefficients for both skewness and kurtosis,(91) Table E-5. For a truly normal distribution, these values should be 0 and 3, respectively. Tables were used to determine if the calculated value fell within acceptable limits to consider the values normally distributed. The acceptance criterion was a significance level greater than 0.01, and all but two parameters met this on the skewness coefficient. For these, modifications were found which gave the desired results. The natural logarithm of the total solids data gave approximate normality, while the ammonia nitrogens follow a normal pattern after two low values are eliminated. The two ammonia nitrogen values are considered valid results, but unusual when determining the distributional nature of these data. The results of the analyses provided the basis for determining the validity of using certain statistical methods for selecting a proper summarizing statistic. No statistical analyses were planned or conducted for the chemical data from the Post-Fair period, and no investigation into their distributional nature was conducted for those data.

c. *Analytical Accuracy*

During Pre-Fair, the accuracy of the laboratory analyses of the effluent samples was investigated using a comparative study between two laboratories, the primary laboratory performing the analysis and an alternate laboratory. For most analyses, a series of samples was prepared using both deionized water and effluent, and both unspiked and spiked samples were used for comparison purposes, with a known standard material obtained from EPA used as the spiking material. For the others, the primary and secondary laboratories performed the analyses on replicate samples taken from the same composite/grab effluent sample. For the spiked samples, the accuracy criterion used was the percent recovery of the spike. For the remainder, the accuracy of the primary laboratory was evaluated by comparing the results to those of the alternate laboratory to determine the consistency of the results obtained.

To ensure that the laboratories performed the analyses in a comparable manner to the routine samples, the laboratories were not informed which were the quality assurance samples nor which method was under study.

(1) *Routine Analyses*

The primary analyses for total and free chlorine and pH were conducted on-site by the SwRI personnel, and EQA was used as the alternate laboratory. Six samples of effluent were taken from the

Table E-3
ROUTINE CHEMICAL ANALYSES OF DAILY COMPOSITES

Run No.	Date	pH	TOC (mg/l)	TSS (mg/l)	Conductivity µmho/cm
Post-Fair					
1	1-21-77	8.3	19	12	1325
2	1-25-77	8.4	30	15	1310
3	1-25-77	8.4	20	9	1310
4	1-30-77	8.5	11	14	1290
5	1-30-77	8.5	16	10	1310
6	2-09-77	8.5	110*	16	1290
7	2-10-77	8.5			1390
10	2-23-77	8.5	19	14	1425
11	2-24-77	8.4	20	13	1450
12	2-24-77	8.4	14	10	1410
13	2-28-77	8.5	29	16	1425
14	3-14-77	8.7	14	36	1425
15	3-16-77	8.6	14	31	1390
16	3-17-77	8.6	20	17	1310
17	3-18-77	8.5	12	10	1425
22	3-25-77	8.5	16	15	1400
23	3-26-77	8.4	16	5	1390
24	3-26-77	8.6	14	40	1400
25	3-27-77	8.5	45	94	1450
26	3-27-77	8.6	18	6	1375
29	4-11-77	8.5	14	36	1325
30	4-12-77	8.5	11	18	1375
31	4-13-77	8.5	12	40	1375
32	4-14-77	8.5	17	28	1390
33	4-19-77	8.4	34	28	1475
34	4-19-77	8.3	34	34	1490
35	4-22-77	8.2	30	17	1550
36	4-23-77	8.3	35	38	1590
37	4-24-77	8.3	41	52	1510
38	4-24-77	8.4	33	43	1500
Mean		8.5	24.8	24.7	1402.7
Std Dev		0.1	19.0	18.5	77.0
CV %		1	77	75	6

*Sample received at 8°C.

Table E-4
SELECTIVE CHEMICAL ANALYSES OF DAILY COMPOSITE (mg/1)

Run No.	Date	TOC	BOD	COD	Total Phosphorus	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia Nitrogen	Organic Nitrogen
2	1-25-77	35	13	96	5.9	0.29	0.19	29.12	4.76
6	2-09-77	110*	9	70	5.0	0.04	0.20	32.6	4.25
25	3-27-77	45	20	205	8.2	0.77	0.59	31.9	11.95
Mean		63.3	14.0	123.7	34.3	0.37	0.33	31.2	6.99
St Dev		40.7	5.6	71.6	28.1	0.37	0.23	1.8	4.3
CV %		64	40	58	82	101	70	6	62

*Sample received at 8°C.

Table E-5
NORMALITY TEST SUMMARY

Parameter	Skewness	Kurtosis	Tests of Hypotheses	
			$\sqrt{b_1} = 0$	$b_2 = 3$
pH	0.16	1.77	OK	<0.01
TOC	0.84	2.61	OK	OK
Total Solids	0.95	3.65	<0.01	OK
ln (total solids)	0.78	3.15	OK	OK
TSS	0.20	1.63	OK	<0.01
Total Phosphorus	0.54	2.86	OK	OK
Hardness	0.29	3.08	OK	OK
Nitrite Nitrogen	−0.09	1.78	OK	<0.01
Nitrate Nitrogen	0.82	3.77	OK	OK
Ammonia Nitrogen	−1.55	6.98	<0.01	<0.01
Ammonia Nitrogen (two low values removed)	0.45	3.08	OK	OK
Organic Nitrogen	−0.57	2.78	OK	OK

daily composite sample and sent to EQA and six portions of the daily composite sample prepared for analysis by the on-site personnel. The results of these analyses are shown in Table E-6.

As can be seen, no chlorine was detectable by either laboratory conducting the total and free chlorine analyses. In the SwRI analyses, the detection limits are 0.1 and 0.05 mg/l for total and free chlorine, respectively, and for the EQA methods, the detection limit is 0.01 mg/l for both determinations.

For the pH determination, the on-site analyses gave an average pH of 8.5 for the six samples compared to 8.4 for the alternate laboratory. This difference is of no practical significance and the analyses can be said to have given comparable results.

Thus, for the three routine on-site analyses, the quality assurance study indicated that the results obtained by the primary analysts were accurate representations of the effluent quality over the period.

The original plan called for EQA to perform the primary analyses for TOC, with alternate analyses performed by SwRI. A total of 8 samples were sent to each laboratory for analysis, consisting of two each of unspiked and spiked deionized water and effluent. The spiking level was 8 mg/l for the effluent and 20 mg/l for the deionized water. The results are summarized in Table E-7.

As can be seen, there are unusual results in the data. First, the results for EQA for the deionized water are higher than their findings for the effluent samples, and second, there is no difference in the results for the spiked and unspiked deionized water samples. The results for SwRI on the deionized water samples are also somewhat unusual, with a value of 20 for an unspiked sample. Using the standard of percent recovery, however, the SwRI results evidenced good accuracy, with 100-percent recovery on the effluent and 87.5 percent on the deionized water. The EQA results are not good, however, with only 69 percent on the effluent and none recovered on the deionized water samples.

The analyses for both total and suspended solids were conducted by PEL as the primary and by EQA as the secondary laboratory. No standard was available for these parameters so a series of replicate samples was used. Three samples were sent to PEL for their usual analyses in addition to the daily sample and 4 samples were sent to EQA from the same daily composite sample. The results are summarized in Table IV.E-8.

Table E-6
QUALITY ASSURANCE STUDY OF ON-SITE ROUTINE ANALYSES

	Total Chlorine[1] (mg/l)		Free Chlorine [2] (mg/l)		pH	
Sample	SwRI	EQA	SwRI	EQA	SwRI	EQA
1	N.D.	N.D.	N.D.	N.D.	8.5	8.4
2	N.D.	N.D.	N.D.	N.D.	8.5	8.4
3	N.D.	N.D.	N.D.	N.D.	8.5	8.4
4	N.D.	N.D.	N.D.	N.D.	8.5	8.4
5	N.D.	N.D.	N.D.	N.D.	8.6	8.4
6	N.D.	N.D.	N.D.	N.D.	8.5	8.4

1. Detection Limit. 0.1 mg/l for SwRI and 0.01 mg/l for EQA.
2. Detection Limit. 0.05 mg/l for SwRI and 0.01 mg/l for EQA.

Table E-7
TOC QUALITY ASSURANCE STUDY (mg/l)

Laboratory	Medium	Spike Level	Samples 1	Samples 2	Average	Amount Recovered	Percent Recovery
EQA	DI-H_2O	0	33	37	30	--	--
		20	30	30	30	0	0
	Effluent	0	12	10	11	--	--
		8	15	18	16.5	5.5	69
SwRI	DI-H_2O	0	4	20	12	--	--
		20	35	24	29.5	17.5	88
	Effluent	0	22	24	23	--	--
		8	32	30	31	8	100

Table E-8
TOTAL AND SUSPENDED SOLIDS QUALITY ASSURANCE STUDY (mg/l)

Parameter		PEL	EQA	t	df	Significance Level
Total Solids		617.0	678	18.52	6	0.01
		612.5	674			
		619.0	674			
	Mean	614.9	673.0			
TSS		64.0	48	6.84	6	0.01
		65.0	44			
		68.0	40			
		64.0	32			
	Mean	65.3	41.0			

To determine if the results were consistent from one laboratory to the next, a two-sample t-test was used, which tests the premise that the two are working around the same true mean value. The calculated t-statistics indicate that the results between the two laboratories are not comparable, however, with EQA being consistently lower on the suspended solids and higher on total solids. Referring to the plant data for that period, on the nearest dates to the collection of these samples the total solids was running near 610 mg/l and TSS near 40 mg/l. The results, then, are closer for PEL in the total and EQA in the suspended solids. It should be noted, however, that these analyses are performed for the city by PEL.

(2) Selective Analyses

The primary analytical laboratory for the selective analyses, with the exception of hardness, was PEL. EQA was used as an alternate on all of the analyses. One series of samples was used in the BOD study, consisting of spiked and unspiked samples of both effluent and deionized water. The standard of accuracy was the percent recovery of the spike and the results are shown in Table E-9.

One of the analyses for BOD was reported as a nondetectable value. A value of one-half of the detection limit was substituted to provide a non-zero number which is necessary to permit this comparative analysis. The level of the spike used was such that there should be little effect on the results from making this substitution. The recovery from the deionized water was 81 percent, while for the effluent it was only 45 percent. However, EQA showed a similar pattern with 70 percent and 16 percent for the deionized and effluent water, respectively. This indicated that an interference from the effluent affected the method results.

The COD study was conducted in a manner similar to the BOD study, utilizing one series of samples. The data are summarized in Table E-10. A problem with the PEL data for the DI-H_2O (deionized water) occurred, resulting from the detection limit of their method, since the results were reported merely as being less than 10 mg/l. For these, the rule of assigning them one-half of the detection limit was not used since it could have a pronounced effect on the results of the study. In the effluent portion of the study, however, there was essentially complete recovery of the spike. In the EQA data, one value fell below the detection limit for the unspiked DI-H_2O, and was assigned a value of 0.5 mg/l. The recovery for the DI-H_2O portion was 81 percent, but was determined to be 145 percent for the effluent. The level of the spike was relatively small compared to the COD level in the effluent, which may have contributed to the unusual result.

Two sets of samples were prepared for the comparative study on the total phosphorus analyses. These were sent at different times during the course of the study, and the results are presented in Table E-11. For PEL, the two data sets are fairly consistent, with 102-percent recovery for both deionized water portions and 81 and 74 percent for the effluent portion in the first and second study, respectively. For EQA, the recoveries from the deionized water were 95 and 98 percent, while the effluent recoveries were 71 and 91 percent, respectively, for the two studies. The conclusion to be drawn is that both laboratories were performing the method well, based on the DI-H_2 portion, and that their analyses were consistent over time. The blank DI-H_2O samples were reported as less than 0.001 and hence treated as zeroes in the analysis.

The hardness determinations were made on-site by SwRI personnel and the secondary analyses performed by EQA. There was no known standard used, so six samples were given to each laboratory for analysis. The results are shown in Table E-12. The mean of the SwRI results is 200.8, and for the EQA data, it is 203.8. Although there was more variability in the SwRI results, ranging from 195 to 210, the mean values can be considered equivalent. Thus, the hardness determination, as in the case of the other on-site analyses, can be considered accurate.

The final comparative studies concerned the nitrogen series: nitrite, nitrate, ammonia, and organic nitrogen. No separate samples were sent for comparative study of nitrite nitrogen, but the design of the quality assurance study was such that the method under study was kept from the analyst. To do this,

Table E-9
BOD QUALITY ASSURANCE STUDY (mg/l)

Laboratory	Medium	Spike Level	Samples		Average	Amount Recovered	Percent Recovery
			1	2			
PEL	DI-H_2O	0	1.3	0.5*	0.9	--	--
		23.25	19.5	20.0	19.75	18.85	81
	Effluent	0	16.3	14.7	15.5	--	--
		9.3	21.2	18.2	19.7	4.2	45
EQA	DI-H_2O	0	1.2	1.3	1.25	--	--
		23.25	18.0	17.0	17.5	16.25	70
	Effluent	0	13.0	13.0	13.0	--	--
		9.3	16.0	13.0	14.5	1.5	16

*Reported as <1.0, assigned one-half value.

Table E-10
COD QUALITY ASSURANCE STUDY (mg/l)

Laboratory	Medium	Spike Level	Samples		Average	Amount Recovered	Percent Recovery
			1	2			
PEL	DI-H_2O	0	<10	<10	<10	-	-
		12.4	18.0	14.0	16.0	-*	-*
	Effluent	0	77.0	75.0	76.0	-	-
		12.4	85.0	93.0	89.0	13.0	105
EQA	DI-H_2O	0	1.2	0.5†	0.85	-	-
		12.4	13.0	8.7	10.85	10.0	81
	Effluent	0	68	66	67.0	-	-
		12.4	83	87	85.0	18.0	145

*Cannot be determined due to magnitude of detection limit.

†Reported as <1.0, assigned one-half value.

Table E-11
TOTAL PHOSPHORUS QUALITY ASSURANCE STUDY (mg/l)

Set	Laboratory	Medium	Spike Level	Samples 1	Samples 2	Avg	Amount Recovered	Percent Recovery
1	PEL	DI-H_2O	0	0.010	0.030	0.020	-	-
			0.713	0.750	0.740	0.745	0.725	102
		Effluent	0	6.70	6.85	6.775	-	-
			0.713	7.30	7.40	7.350	0.575	81
	EQA	DI-H_2O	0	0.025	0.015	0.020	-	-
			0.713	0.724	0.675	0.700	0.680	95
		Effluent	0	6.40	6.62	6.510	-	-
			0.713	7.11	6.92	7.015	0.505	71
2	PEL	DI-H_2O	0	0.005*	0.005*	0.005	-	-
			1.07	1.10	1.10	1.10	1.095	102
		Effluent	0	6.70	6.70	6.70	-	-
			0.713	7.35	7.10	7.225	0.525	74
	EQA	DI-H_2O	0	0.000†	0.000†	0.000	-	-
			1.07	1.05	1.05	1.05	1.05	98
		Effluent	0	6.7	6.6	6.65	-	-
			0.713	7.3	7.3	7.30	0.65	91

*Reported as <0.01, assigned one-half 0.005.
†Reported as <0.001,assigned value of 0.000.

Table E-12
HARDNESS QUALITY ASSURANCE STUDY (mg/l)

Sample	SwRI	EQA
1	205	204
2	195	205
3	200	206
4	195	202
5	200	204
6	210	202
Mean	200.8	203.8

the entire series of methods was run on a bottle for QA analyses as usual, according to which method of sample preparation was used. As a result, there were three sets of analyses on effluent for nitrite nitrogen, those made in the total phosphorus and BOD analyses. The statistical analysis of these data was performed using an Analysis of Variance (ANOVA) with factors of laboratories and sets, where a set is four effluent samples used for one of the preceding analyses. The data and results are summarized in Table A-13.

The laboratories factor in the analysis was significant, meaning that the two labs were obtaining different results. A further investigation, however, revealed that the observed difference was of too low an order to be meaningful. The sample mean of the PEL results over the 12 runs was 0.071, while for EQA the value was 0.074, which is of no practical significance. As a result, the PEL analyses can be said to be representative of the nitrite nitrogen levels present at the site.

The nitrate nitrogen study was conducted in the same manner as the total phosphorus study, i.e., using two sets of samples sent at different times during the course of the test. The results are summarized in Table E-14.

The PEL results for the first set of nitrate nitrogen analyses were similar to the results for other methods. There was essentially 100-percent recovery of the spike for the deionized water, and somewhat less for the effluent. The value used for the unspiked DI-H_2O was again one-half of the detection limit, since due to the detection limit and spike level this can have little effect on the results. The EQA data were not as good, however, evidencing some positive bias on both the DI-H_2O and effluent samples.

On the second set of samples, the PEL results were similar, with 90-percent recovery from the deionized water and 79 percent from the effluent. The EQA data were better than the previous set, but still showed a tendency to obtain high values. The recovery factors for the deionized and effluent water samples were 107 and 109, respectively.

However, the study indicated that the primary laboratory was performing adequately. The recovery from the non-interfering medium was 90-100 percent, and the duplicate samples showed good agreement. It should be noted that the analyst was unaware which of the samples were duplicates.

The ammonia-nitrogen study was conducted using two series of samples as in the nitrate nitrogen study. There were problems encountered in this study, however. The known standard that was used for spiking the samples was not of sufficient concentration nor quantity to allow the waste-water samples to be spiked at an appropriate level. In addition, the detection limit on the PEL method was too high to prevent a good determination of the recovery from the DI-H_2O samples. The results are shown in Table E-15.

For PEL in the first series of samples, the practice of using one-half the detection limit for non-detection results was followed, but does not allow a good determination of recovery. The percent recovery is 56 using the value of 0.30 for the blank, but would be over 70 percent if there were 0.05 mg/l or less present in the deionized water as the EQA results indicate. The effluent was spiked at a level which resulted in the study's being inconclusive due to the variation in the analytical results.

The EQA results were somewhat better. The detection limit on their analyses was given as 0.05 mg/l and a recovery of 80 percent was obtained from the DI-H_2O. This is not significantly different from the result PEL would obtain using their own results and the EQA blank value, however. The EQA effluent values for ammonia show much better results than PEL, both in their percentage recovery and in their consistency from sample to sample.

In the second set of samples, the PEL results were equivalent to the first set of the DI-H_2O samples, but were improved for the wastewater samples. The higher spike level contributed to this, but a still greater spike would have been desirable, if possible. The EQA data were equivalent to the first set, with consistent results from duplicate samples and approximately equal recovery factors for both the deionized water and effluent samples.

Table E-13

NITRITE NITROGEN QUALITY ASSURANCE STUDY (mg/l)

Set*	Sample	Laboratories	
		PEL	EQA
1	1	0.06	0.06
	2	0.06	0.061
	3	0.06	0.061
	4	0.06	0.06
2	1	0.06	0.061
	2	0.06	0.065
	3	0.06	0.063
	4	0.06	0.064
3	1	0.095	0.096
	2	0.095	0.10
	3	0.10	0.10
	4	0.09	0.10
Means		0.071	0.074

ANOVA Table

Source	df	SS	MS	F
Sets	2	0.00693	0.00347	347
Laboratories	1	0.00006	0.00006	6.00†
Error	20	0.00023	0.00001	
Total	23			

*Sets 1 and 2 from Total Phosphorus study--set 3 from COD study.
†Significant at 0.05 level.

Table E-14

NITRATE NITROGEN QUALITY ASSURANCE STUDY (mg/l)

Set	Laboratory	Medium	Spike Level	Sample 1	Sample 2	Avg	Amount Recovered	Percent Recovery
1	PEL	DI-H_2O	0	0.01*	0.01*	0.01	-	-
			1.11	1.12	1.12	1.12	1.11	100
		Effluent	0	0.04	0.03	0.035	-	-
			0.20	0.15	0.155	0.153	0.118	59
	EQA	DI-H_2O	0	0.02	0.01*	0.015	-	-
			1.11	2.30	1.30	1.80	1.785	161
		Effluent	0	0.04	0.08	0.06	-	-
			0.20	0.34	0.30	0.32	0.26	130
2	PEL	DI-H_2O	0	0.01*	0.01*	0.01	-	-
			1.67	1.525	1.515	1.52	1.51	90
		Effluent	0	0.035	0.035	0.035	-	-
			1.11	0.875	0.95	0.913	0.878	79
	EQA	DI-H_2O	0	0.005†	0.005†	0.005	-	-
			1.67	1.80	1.80	1.80	1.795	107
		Effluent	0	0.04	0.04	0.04	-	-
			1.11	1.2	1.3	1.25	1.21	109

*Reported as <0.02, assigned one-half value.
†Reported as <0.01, assigned one-half value.

Table E-15

AMMONIA NITROGEN QUALITY ASSURANCE STUDY (mg/l)

Set	Laboratory	Medium	Spike Level	Sample 1	Sample 2	Avg	Amount Recovered	Percent Recovery
1	PEL	DI-H_2O	0	0.30*	0.30*	0.30	-	-
			1.47	1.12	1.12	1.12	0.82	56
		Effluent	0	26.88	27.44	27.16	-	-
			0.44	28.56	27.44	28.00	0.84	191
	EQA	DI-H_2O	0	0.025†	0.025†	0.025	-	-
			1.47	1.20	1.20	1.20	1.175	80
		Effluent	0	24.8	25.1	24.95	-	-
			0.44	25.2	25.4	25.30	0.35	80
2	PEL	DI-H_2O	0	0.30*	0.30*	0.30	-	-
			2.20	1.68	1.82	1.75	1.45	66
		Effluent	0	28.84	28.00	28.42	-	-
			1.47	29.96	28.84	29.40	0.98	67
	EQA	DI-H_2O	0	0.025†	0.025†	0.025	-	-
			2.20	1.80	1.80	1.80	1.775	81
		Effluent	0	26.6	26.6	26.60	-	-
			1.47	28.1	27.6	27.85	1.25	85

*Reported as <0.60, assigned one-half value.
†Reported as <0.05, assigned one-half value.

The final quality assurance study for the chemical constituents concerned the organic nitrogen determinations. As in the nitrite nitrogen study, no samples were specifically prepared for this analysis. The organic nitrogen determinations from the ammonia and nitrate nitrogen studies and from the COD study were used to obtain replicate analyses on effluent samples. These were submitted to an ANOVA as were the nitrite nitrogen determinations. The data used and the results obtained are summarized in Table E-16.

From the laboratories factor, it is determined that there was a difference in the results obtained from the two laboratories, and that EQA obtained consistently higher results. The value of 11 obtained on the first set contributes more than one-third of the difference, but even if this value were treated as an outlier, the means would be considered distinct. However, for the methodology used, a difference of about 1 mg/l in the mean values for the laboratories over the 12 samples used is not considered to be of any practical significance.

d. *Analytical Precision*

The precision of the chemical analyses data generated during the Pre-Fair study was evaluated to identify sources, if any, of significant variability. To further identify to what extent individual sample handling and analytical procedures contributed to the overall variability in the data, three variance components were calculated. These components included repeatability (variance among repeat analyses of the same effluent sample); shipping and analysis (variance among aliquots taken from the same effluent sample with each aliquot transported separately to the analytical laboratory for analysis); and day-to-day (variance associated with daily changes in wastewater quality). This statistical analysis was performed for all routine and selective chemical analyses except total and free chlorine, pH, and hardness. These were not included because all were single determination-type analyses that were conducted on-site for which variability associated with repeatability and shipping and analyses were not relevant concerns.

To calculate the repeatability variance component, individual aliquot analytical results from the daily (composite) effluent samples were used. For those analyses conducted on a routine basis, only a representative number of samples, covering the entire period of the study, were selected at random for this calculation. This was done because the large number of routine samples collected was in excess of those necessary to provide a sufficient number of degrees of freedom for this analysis. All available data were used for this calculation for the analyses conducted on a selective basis. For each set of results, an individual standard deviation was calculated and then a "pooled" variance and standard deviation calculated to represent the repeatability variance component.

The variance associated with shipping and analysis was calculated from a special set of six effluent aliquots taken from a single large-volume effluent sample. The analytical results and the standard deviation for each set of six analyses are presented in Table E-17.

The day-to-day variance component was derived from the ANOVA of the chemical data presented in section f. below. The mean square for error from the ANOVA was used because it represents the daily variation in the chemical analysis without inclusion of weekly trends.

The three variance components of each analysis are presented in Table E-18. For total solids, the logarithmic transformation was used to normalize the data and the pooled variance and standard deviation calculated in the transformed scale. Exponentiating this gives an analogous result to a coefficient of variation, where a value of 1.02 represents a 2-percent variability in the analyses. The coefficient of variation from the precision samples is calculated as 2.2%, which indicates variability in sample analyses due to shipping and handling samples was not significant and thus, the majority of the variability resulted from the changing water quality (day-to-day variance).

The remainder of the data were analyzed in their untransformed state and the results presented in terms of standard deviations. The only analyses to exhibit a significant difference in the shipping

Table E-16
ORGANIC NITROGEN QUALITY ASSURANCE STUDY

		Laboratories	
Set*	Sample	PEL	EQA
1	1	5.60	6.0
	2	5.32	6.0
	3	3.22	11
	4	3.92	6.0
2	1	2.52	3.6
	2	2.52	3.6
	3	1.54	3.0
	4	3.08	3.4
3	1	2.80	3.1
	2	3.78	3.0
	3	3.92	3.3
	4	3.64	3.8
Mean		3.49	4.65

ANOVA Table

Source	df	SS	MS	F
Sets	2	40.64	20.32	11.95
Laboratories	1	8.07	8.07	4.75†
Error	20	34.02	1.70	
Total	23	82.73		

---

*Sets 1, 2 from NO_3-NH_3 nitrogen studies, set 3 from BOD study.
†Significant at 0.05 level.

Table E-17

CHEMICAL QUALITY ASSURANCE PRECISION STUDY—ANALYTICAL RESULTS (mg/l)

	Parameter									
Sample	Total* Solids	TSS	TOC	BOD	COD	Total Phosphorus	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia Nitrogen	Organic Nitrogen
1	612.5	29.0	22	15	113	6.3	0.05	<0.02	24.64	6.58
2	613.5	28.0	23	16	109	6.3	0.05	<0.02	25.48	5.6
3	620.0	29.0	22	15	105	6.4	0.05	<0.02	25.20	6.16
4	583.5	26.0	70	16	111	6.6	0.05	<0.02	25.20	6.16
5	601.0	34.0	42	16	113	6.4	0.05	<0.02	25.20	6.16
6	596.0	36.0	41	15	115	6.3	0.05	<0.02	25.20	6.58
Standard Deviations	2%	3.83	10.5	0.5	3.6	0.11	0.0	0.0	0.28	0.36

*Transformed by natural logarithm, coefficient of variation shown for standard deviation.

Table E-18

CHEMICAL QUALITY ASSURANCE PRECISION STUDY—PRECISION ESTIMATE (mg/l)

	Parameter Standard Deviation									
Variance Component	Total* Solids	TSS	TOC	BOD	COD	Total Phosphorus	Nitrite Nitrogen	Nitrate Nitrogen	Ammonia Nitrogen	Organic Nitrogen
Repeatability	2%	2.24	1.17	1.4	3.4	0.14	0.004	0.005	0.41	0.28
Shipping and Analysis	2%	3.83†	10.5†	0.5	3.6	0.11	0.0	0.0	0.28	0.36
Day-to-Day	7%	9.98	7.4	3.4	12.5	0.70	0.045	0.03	2.17	1.21

*Coefficients of variation for standard deviation.
†Significant at 0.05 level.

Table E-19
COMPARATIVE ORGANIC PARAMETER

Run No.	COD/TOC	Ratios COD/BOD	TOC/BOD
1	5.5	5.5	1.0
3	2.3	5.5	2.3
5	2.9	7.4	2.6
33	–*	4.8	–*
35	–*	4.6	–*
37	2.9	6.5	2.3
71	2.7	5.0	1.8
61	3.1	8.8	2.9
41	3.3	5.5	1.7
67	2.7	4.7	1.8
75	2.9	5.2	1.8
39	3.0	5.6	1.9
99	2.9	5.4	1.9
63	3.3	7.3	2.2
97	2.9	5.8	2.0
73	3.5	5.2	1.5
69	3.1	5.9	1.9
95	2.9	4.3	1.5
77	–*	5.3	–*
65	3.1	6.5	2.1
43	3.2	4.0	1.2
50	3.2	4.8	1.5
52	2.7	3.5	1.3
56	3.3	4.6	1.4
58	3.3	4.3	1.3
		Correlation Coefficient	
	0.827	0.652	0.567
		t-Value	
	6.591	4.125	3.079
		Significance Level	
	<0.001	<0.001	0.006

*Probable contamination in TOC value.

Table E-20
WEEKLY-DAILY ANOVA SUMMARY

Parameter	F-Ratio	Degrees of Freedom		Significance Level
		f_1	f_2	
pH	17.00	6	35	<0.005
TOC	6.13	6	33	<0.005
Total Solids	15.34	6	35	<0.005
TSS	22.74	6	35	<0.005
BOD	3.95	6	14	0.02
COD	12.37	6	14	<0.005
Total Phosphorus	3.63	6	14	0.02
Hardness	11.3	6	14	<0.005
Nitrite Nitrogen	3.50	6	14	0.025
Nitrate Nitrogen	1.46	6	14	NS*
Ammonia Nitrogen	3.59	6	14	0.025
Organic Nitrogen	5.69	6	14	<0.005

*Not significant.

Table E-21
WEEKLY-DAILY ANOVA MEANS SEPARATION

Parameter	Weeks							LSD
	1	2	3	4	5	6	7	
pH	8.40	8.42	8.30	8.27	8.31	8.64	8.68	0.10
TOC	38.75	42.75	41.57	26.86	27.57	27.67	24.40	10.40
Total Solids	604.75	640.70	646.79	614.50	603.86	675.86	726.30	29.98
TSS	49.50	60.00	50.86	21.86	12.21	13.21	34.10	11.29
BOD	25.30	24.00	21.00	14.27	15.85	16.50	18.33	4.68
COD	138.0	135.0	123.3	85.0	83.0	82.7	78.1	17.4
Total Phosphorus	6.80	6.85	5.09	4.70	5.53	5.45	4.93	0.97
Hardness	215.0	205.0	223.8	233.3	235.0	261.7	261.7	14.4
Nitrite Nitrogen	0.065	0.115	0.158	0.185	0.211	0.157	0.202	0.062
Ammonia Nitrogen	23.895	22.540	24.570	25.107	26.158	23.487	19.040	3.002
Organic Nitrogen	7.325	6.860	6.160	3.453	3.418	5.043	7.093	1.679

From Table E-21, an improvement in the water quality was seen to occur from the third to the fourth week, when all organic and demand analyses indicate a break. From the sixth to the seventh week, several of the constituents show an increase, notably total solids and TSS, and the hardness and pH values increased significantly one week earlier.

Similar analyses were not conducted on the Post-Fair sampling period results due to the Post-Fair objectives which were primarily to develop the microbiological dispersion model. The focus of the Post-Fair study was on the microorganism groups and sufficient characterization of the wastewater had been ascertained by that time.

APPENDIX F
MICROORGANISM CONCENTRATION DATA FOR THE MICROBIOLOGICAL AEROSOL RUNS

APPENDIX F
LIST OF TABLES

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Table F-1
PRE-FAIR MICROBIOLOGICAL AEROSOL RUN STANDARD PLATE COUNTS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Wastewater Sample (No./100 ml)	Aerosol Samples (No./m³ of air)														
			Upwind Samples	Downwind Samplers Perpendicular Distance from Wet Line Edge													
				5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1	5-4-76	110 × 10^6	4600[j]	9850[b,d]	1400		830	40000[b]					110		140		
M1-2	5-5-76	120 × 10^6	2000	6700[b,d]	6000		8600[c]	73000[b,h]					5500[j]		6500		
M1-3	5-5-76		680		4900		9800[c]	122000[e]					1500		1300		
M1-4	5-13-76	101 × 10^6	3500	11000[c]	3700		1100						720[b,d]		350		
M1-5	5-13-76	167 × 10^6	35000	2600	2100		2000								1200[j]		
M1-6	5-17-76	76 × 10^6	350[j]	1700	1600		3600[b]						54000[e,h]		420[h,j]		
M1-7	5-17-76	46 × 10^6	620	2000	2000[j,h]		1700[e]						34000[h]		620[h]		
M1-8	5-21-76	70 × 10^6	100	610000	1000		3200[j]	567000[h]					340	360[h]			
M1-9	5-24-76	104 × 10^6	3300	6300[g]	3000		51700						1800		640		
M1-10	5-24-76	145 × 10^6	3700		4500		19000	152000[j]		2200			2000[h]		690[h]		
M1-11	5-25-76	35 × 10^6	840		3000		47000[c]	50000		2000			2200[h]		1400[h]		
M1-12	5-27-76	34 × 10^6	150		850		2100[c]	700000[h]		M[q]			750		580[h]		
M1-13	5-27-76	26 × 10^6	64				2000	530000[h]					790[h]		1400		980[j]
M1-14	5-27-76	73 × 10^6	1200				1100						870		1200		1900[h]
M1-15	6-3-76	45 × 10^6	5100		1800		9200	M[q]		1400[h]			1900		1300	1400[h]	
M1-31	6-14-76	16 × 10^6	220		3500		3000			3800			2000	2700[j]			
M1-32	6-15-76	20 × 10^6			15000	1500	1200			3800	6300	>83000	M[o]				
M1-33	6-15-76	95 × 10^6	680		7000[e]		3600	5000		5300[h]	3300	2000	4400[o]				
M1-34	6-16-76	54 × 10^6	1600				1900	2500[j]	1200	1600	1600		3000				
M1-35	6-17-76	76 × 10^6	300		5200	1000	2900			1600	1900[j]		1300	1300			

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Table F-2
POST-FAIR MICROBIOLOGICAL AEROSOL RUN STANDARD PLATE COUNTS BY SAMPLER DISTANCE

Aerosol Run No	Run Date	Wastewater Sample (No./100 ml)	Aerosol Samples (No./m^3 of air)								
				Downwind Samplers – Perpendicular Distance from Wet Line Edge							
								Distant Samplers			
			Upwind Sampler	50 m Left	50 m Right	100 m Left	100 m Right	Left	Center	Right
M2-1	1-21-77	15 × 10^6	1300^j	47000	830	>1000000	830	370^h	430	260^j
M2-2	1-25-77	90 × 10^6	$900^{h,j}$	230	200	180	470	1400^h	1700^j	4200^j
M2-3	1-25-77	113 × 10^6	2000^j	2200	1500^j	4500	3800	M^s	1600	1200
M2-4	1-30-77	27 × 10^6	750	530	3100^j	160	430	2500	820^m	570
M2-5	1-30-77	30 × 10^6	1300	870^h	1600	750	$1100^{d,j}$	1200	4500^m	1800
M2-6	2-9-77	7.0 × 10^6	$>330000^m$	480	290	92	500	75	>33000	95
M2-10	2-23-77	8.0 × 10^6	100000	63	>33000	300^j	320^j	2300	13000	160
M2-11	2-24-77	2.7 × 10^6	280000	73	34000	25000	100	170^j	>33000	68
M2-12	2-24-77	2.1 × 10^6	140000^j	95	12000	53000	500	180^j	>33000	46^d
M2-13	2-28-77	12 × 10^6	240000	73	220000	340^d	92^d	58000	1100000	$2400^{l,m}$
M2-14	3-14-77	21 × 10^6	1500	$>10000^k$	2800	$>10000^{j,k}$	$>10000^k$	270^j	290	$>10000^k$
M2-15	3-16-77	73 × 10^6	<33	1400	330	120	1200	330	200^j	$>10000^k$
M2-16	3-17-77	105 × 10^6	67	1100	1300	150	83^j	22^j	130	430
M2-17	3-18-77	76 × 10^6	250	950	720^h	17000	2400	150	65	360
M2-22	3-25-77	2.2 × 10^6	98	60	72	72	43	450	23^j	150
M2-23	3-26-77	20 × 10^6	61	92	40	97	110	180	13	16
M2-24	3-26-77	41 × 10^6	33	190	190	33^d	110^d	730	64	52
M2-25	3-27-77	26 × 10^6	67	310	270	98	150^d	45	46	55^d
M2-26	3-27-77	34 × 10^6	90^j	82	100	97	45	$72^{j,p}$	170	520^j
M2-29	4-11-77	44 × 10^6	430	1300	1900	1700^j	3200	430	270^j	380
M2-30	4-12-77	27 × 10^6	1600	470	550	750	870	650^j	680	3700
M2-31	4-13-77	67 × 10^6	150	26000	1000	500	530	930	580	220
M2-32	4-14-77	75 × 10^6	620	520	$>10000^k$	$>10000^k$	520	350	280	350
M2-33	4-19-77	8.6 × 10^6	170	3000	23000	$>10000^k$	$>10000^k$	3700^j	1100	$>10000^k$
M2-34	4-19-77	15 × 10^6	420	4800	2300^d	$>10000^{j,k}$	1900	1300	970	1400
M2-35	4-22-77	6.9 × 10^6	250	4700	170	500	430	70	170	2700
M2-36	4-23-77	1.9 × 10^6	130	$>10000^k$	130	130^j	170	830	150	210
M2-37	4-24-77	16 × 10^6	$690^{d,j}$	$>10000^k$	600	290	630	3800^m	520	1100^d
M2-38	4-24-77	15 × 10^6	2800	$>10000^k$	2100	870	1200	210	300	950

Table F-3

PRE-FAIR MICROBIOLOGICAL AEROSOL RUN TOTAL COLIFORM CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No	Run Date	Wastewater Sample (MFC/100 ml)	Aerosol Samples (MFC/m³ of air)														
			Upwind Sampler	Downwind Samplers Perpendicular Distance from Wet Line Edge													
				5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1	5-4-76	1480 × 10^3	<6^{j}	8^{b,d}	8		<7	<7^{b}					<6		<5		
M1-2	5-5-76	2070 × 10^3	<0.6	9.2^{b,d}	10.5		17.2^{c}	20.0^{b,h}					8.3^{i}		5.1		
M1-3	5-5-76	2140 × 10^3	<0.6	12.7	8.1		10.9^{c}	12.6^{e}					3.0		0.5		
M1-4	5-13-76	690 × 10^3	<0.6	1.7^{c}	2.1		<0.7						<0.8^{h,d}		<0.5		
M1-5	5-13-76	720 × 10^3	<0.6	5.8	1.4		<0.7								<0.5^{j}		
M1-6	5-17-76	930 × 10^3	<0.4^{j}	6.5	4.6		7.7^{b}						TNIC^{h,k}		0.6^{h,j}		
M1-7	5-17-76	700 × 10^3	<0.4	4.3	1.2^{f,h}		5.2^{e}						TNIC^{h,k}		0.5^{h}		
M1-8	5-21-76	950 × 10^3	<0.4	10.8	15.5		1.1^{j}	TNIC^{k}					<0.5	0.9^{h}			
M1-9	5-24-76	1040 × 10^3	<0.6	18.0^{g}	38		TNIC^{k}						5.2		4.4		
M1-10	5-24-76	1280 × 10^3	0.5		57		93	TNIC^{j,k}		46			32^{h}		4.9^{h}		
M1-11	5-25-76	1100 × 10^3	<0.4		43		46^{c}	TNIC^{k}		53			8.3^{h}		<0.6^{h}		
M1-12	5-27-76	470 × 10^3	<0.4		2.0		6.5^{c}	TNIC^{k}		M^{a}			1.4		<0.6^{h}		
M1-13	5-27-76	690 × 10^3	<0.6				11.7	TNIC^{k}					6.2^{h}		4.3		26^{j}
M1-14	5-27-76	750 × 10^3	<0.4				47						14.5		4.1		2.2^{h}
M1-15	6-3-76	588 × 10^3	<0.4		3.2		2.2	TNIC^{k}		38.5^{h}			2.1		0.9	2.0^{h}	
M1-31	6-14-76	970 × 10^3	<0.2		13.2		4.7			2.6			0.4	1.9^{j}			
M1-32	6-15-76	265 × 10^3			0.8	1.0	<1.5			0.9	<0.5	TNIC^{k}	M^{n}				
M1-33	6-15-76	170 × 10^3	<0.3		≤0.5^{n}		<0.4	1.5		<0.6^{b}	2.0	1.8	≤0.5^{o}				
M1-34	6-16-76	550 × 10^3	<0.3				1.7	2.3^{j}	3.8	1.6	<0.5		3.1				
M1-35	6-17-76	350 × 10^3	<0.4		19.3	30.5	12.0			6.6	5.1^{j}		2.0	2.6			

Table F-4

POST-FAIR MICROBIOLOGICAL AEROSOL RUN TOTAL COLIFORM CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No	Run Date	Wastewater Sample (MFC/100 ml)	Aerosol Samples (MFC/m³ of air)								
			Upwind Sampler	Downwind Samplers–Perpendicular Distance from Wet Line Edge							
				50 m Left	50 m Right	100 m Left	100 m Right	Distant Samplers Left	Distant Samplers Center	Distant Samplers Right
M2-1	1-21-77	60 × 10^6	1.8^{j}	6.7	7.5	<0.3	0.8	$<0.3^{h}$	<0.3	$<0.3^{j}$
M2-2	1-25-77	280 × 10^6	$<0.2^{h,j}$	2.0	1.5	0.4	1.6	$<0.2^{h}$	0.7^{j}	$<0.2^{j}$
M2-3	1-25-77	450 × 10^6	$<0.2^{j}$	37	31^{j}	15.2	10.5	M^{s}	0.3	<0.2
M2-4	1-30-77	260 × 10^6	<0.2	6.5	5.8^{j}	2.0	1.3	<0.2	$<0.2^{m}$	<0.2
M2-5	1-30-77	340 × 10^6	<0.2	4.8^{h}	5.5	2.6	$3.1^{d,i}$	<0.2	1.1^{m}	<0.2
M2-6	2-9-77	220 × 10^6	$<0.2^{m}$	2.1	1.9	0.2	0.2	0.2	<0.2	<0.2
M2-10	2-23-77	410 × 10^6	$\underline{\text{TNTC}^{k}}$	1.3	5.5	4.7^{j}	5.3^{i}	0.2	0.2	<0.2
M2-11	2-24-77	340 × 10^6	$\underline{\text{TNTC}^{k}}$	3.1	2.2	0.9	1.3	$<0.2^{j}$	<0.2	<0.2
M2-12	2-24-77	360 × 10^6	$\underline{\text{TNTC}^{j,k}}$	0.3	2.9	1.3	0.2	$<0.2^{j}$	<0.2	$<0.2^{d}$
M2-13	2-28-77	390 × 10^6	$\underline{10.0}$	1.7	2.7	2.8^{d}	3.3^{d}	<0.2	1.0	$<0.2^{i,m}$
M2-14	3-14-77	420 × 10^6	<0.2	13.0	10.8	1.1^{j}	1.3	$<0.2^{j}$	<0.2	<0.2
M2-15	3-16-77	690 × 10^6	<0.2	5.3	4.5	1.6	1.1	<0.2	$<0.2^{j}$	<0.2
M2-16	3-17-77	1100 × 10^6	<0.2	9.7	12.2	4.3	1.8^{j}	$<0.2^{j}$	0.2	<0.2
M2-17	3-18-77	1200 × 10^6	<0.2	3.7	7.7^{h}	5.7	2.4	<0.2	0.2	0.2
M2-22	3-25-77	860 × 10^6	<0.2	2.0	2.0	0.4	0.2	<0.2	$<0.2^{j}$	<0.2
M2-23	3-26-77	700 × 10^6	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
M2-24	3-26-77	740 × 10^6	<0.2	1.8	0.6	$<0.1^{d}$	0.2^{d}	0.2	<0.2	<0.2
M2-25	3-27-77	730 × 10^6	<0.2	2.2	3.8	0.7	$<0.2^{d}$	<0.2	<0.2	$<0.2^{d}$
M2-26	3-27-77	670 × 10^6	$<0.2^{j}$	0.3	0.4	<0.2	<0.2	$\underline{<0.2^{i,p}}$	<0.2	$<0.2^{j}$
M2-29	4-11-77	1600 × 10^6	<0.2	0.2	<0.2	$<0.2^{i}$	<0.2	<0.2	$<0.2^{j}$	<0.2
M2-30	4-12-77	640 × 10^6	<0.2	1.2	0.7	2.0	0.6	$<0.2^{j}$	<0.2	<0.2
M2-31	4-13-77	450 × 10^6	<0.2	7.8	7.5	M^{s}	4.8	0.2	0.2	0.2
M2-32	4-14-77	1200 × 10^6	<0.2	2.0	2.3	1.5	1.5	<0.2	<0.2	<0.2
M2-33	4-19-77	290 × 10^6	<0.2	14.0	13.5	$\underline{\text{TNTC}^{k}}$	0.2	$<0.2^{j}$	<0.2	<0.2
M2-34	4-19-77	540 × 10^6	0.8	5.0	8.4^{d}	$<0.2^{i}$	<0.2	1.0	<0.2	<0.2
M2-35	4-22-77	360 × 10^6	<0.2	$\underline{0.2}$	2.0	2.0	1.7	<0.2	0.2	<0.2
M2-36	4-23-77	410 × 10^6	<0.2	$\underline{<0.2}$	1.3	0.2^{j}	<0.2	0.2	<0.2	<0.2
M2-37	4-24-77	450 × 10^6	$<0.2^{d,i}$	1.7	2.5	<0.2	0.5	$<0.2^{m}$	<0.2	$<0.2^{d}$
M2-38	4-24-77	410 × 10^6	<0.2	1.1	0.7	<0.2	<0.2	<0.2	<0.2	<0.2

Table F-5
PRE-FAIR MICROBIOLOGICAL AEROSOL RUN FECAL COLIFORM CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Wastewater Sample (MFC/100 ml)	Aerosol Samples (MFC/m³ of air)														
			Upwind Sampler	Downwind Samplers - Perpendicular Distance from Wet Line Edge													
				5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1	5-4-76	150 × 10³	$<1.0^{j}$	$1.8^{h,g}$	<0.9		<1.1	$<1.1^{b}$					<1.0		<0.8		
M1-2	5-5-76	186 × 10³	<0.6	$2.0^{h,g}$	2.1		4.4^{c}	$2.1^{b,h}$					1.2^{j}		0.2		
M1-3	5-5-76	174 × 10³	<0.6	0.9	1.7		3.0^{c}	1.0^{e}					<0.3		<0.3		
M1-4	5-13-76	47 × 10³	<0.6	$<0.4^{c}$	<0.3		<0.4						$<0.5^{h,d}$		<0.3		
M1-5	5-13-76	180 × 10³	<0.4	1.1	0.7		<0.4								$<0.4^{i}$		
M1-6	5-17-76	75 × 10³	$<0.3^{j}$	1.1	0.3		1.4^{b}						$TNTC^{h,k}$		$<0.2^{h,j}$		
M1-7	5-17-76	110 × 10³	<0.3	0.6	$1.5^{f,h}$		$<0.3^{e}$						$<0.3^{h}$		0.5^{h}		
M1-8	5-21-76	80 × 10³	<0.3	1.6	<0.6		$<0.3^{j}$	$TNTC^{h,k}$					<0.3	$<0.2^{h}$			
M1-9	5-24-76	81 × 10³	<0.3	3.1^{g}	2.3		2.0						1.2		0.2		
M1-10	5-24-76	125 × 10³	0.3		9.5		12.2	$TNTC^{j,k}$		3.8			5.6^{h}		0.5^{h}		
M1-11	5-25-76	126 × 10³	<0.4		6.6		6.2^{c}	$TNTC^{k}$		1.3			0.5^{h}		$<0.6^{h}$		
M1-12	5-27-76	M^{s}	M^{s}		M^{s}		M^{s}	M^{s}		M^{q}			M^{s}		M^{s}		
M1-13	5-27-76	M^{s}	M^{s}				M^{s}	M^{s}					M^{s}		M^{s}		M^{s}
M1-14	5-27-76	M^{s}	M^{s}				M^{s}						M^{s}		M^{s}		M^{s}
M1-15	6-3-76	57 × 10³	<0.5		1.8		1.9	$TNTC^{k}$		0.2^{h}			0.5		0.2	$<0.3^{h}$	
M1-31	6-14-76	137 × 10³	<0.2		2.9		0.6			0.6			0.2	0.2^{j}			
M1-32	6-15-76	24 × 10³			<0.3	0.3	1.0			<0.3	<0.2	$TNTC^{k}$	M^{o}				
M1-33	6-15-76	34 × 10³	<0.2		$<0.3^{n}$		<0.3	<0.3		$<0.4^{b}$	<0.2	<0.3	$<0.3^{o}$				
M1-34	6-16-76	81 × 10³	<0.3				0.4	1.0^{j}	0.6	0.5	<0.2		0.7				
M1-35	6-17-76	45 × 10³	<0.2		4.9	4.4	9.9			1.2	0.6^{j}		0.4	0.5			

Table F-6
PRE-FAIR MICROBIOLOGICAL AEROSOL RUN COLIPHAGE CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Wastewater Sample (PFU/l)	Aerosol Samples (PFU/m³ of air)														
			Upwind Sampler	Downwind Samplers - Perpendicular Distance from Wet Line Edge													
				5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1	5-4-76	-	$<0.6^{j}$	$<0.6^{h,g}$	<0.5		<0.7	$<0.7^{h,k}$					<0.6		<0.5		
M1-2	5-5-76	110×10^{3}	<0.4	$<0.3^{h,g}$	<0.3		$<0.4^{c}$	$<0.4^{h,h,k}$					$<0.4^{i}$		<0.3		
M1-3	5-5-76	95×10^{3}	<0.4	<0.3	0.3		0.4^{c}	$<0.5^{c,h}$					<0.4		<0.3		
M1-4	5-13-76	110×10^{3}	0.1	$<0.2^{c}$	<0.1		<0.1						$0.2^{h,d}$		<0.1		
M1-5	5-13-76	170×10^{3}	<0.1	<0.2	0.1		<0.1								0.1^{i}		
M1-6	5-17-76	220×10^{3}	$<0.1^{j}$	1.0	0.6		0.8^{b}						$<0.2^{c,h}$		$<0.1^{h,j}$		
M1-7	5-17-76	230×10^{3}	<0.1	0.2	$<0.2^{f,h}$		0.3^{e}						$<0.1^{h}$		0.1^{h}		
M1-8	5-21-76	61×10^{3}	<0.1	0.7	0.4		0.1^{j}	0.3^{h}					<0.1	0.1^{k}			
M1-9	5-24-76	95×10^{3}	$<0.1^{k}$	1.1^{g}	0.1		1.2^{k}						0.8		0.3		
M1-10	5-24-76	130×10^{3}	$<0.1^{k}$		2.0		3.7	1.1^{k}		1.4^{k}			2.6^{h}		0.2^{h}		
M1-11	5-25-76	140×10^{3}	$<0.1^{k}$		2.3		$0.8^{c,k}$	1.4		1.1			0.6^{h}		0.4^{h}		
M1-12	5-27-76	110×10^{3}	$<0.1^{k}$		0.9		$0.7^{c,k}$	$0.3^{h,k}$		M^{q}			0.2		0.1^{h}		
M1-13	5-27-76	170×10^{3}	$<0.1^{k}$				1.1	$0.1^{h,k}$					1.0^{h}		0.7		0.2^{j}
M1-14	5-27-76	210×10^{3}	$<0.1^{k}$				3.3						0.8		0.6		0.2^{h}
M1-15	6-3-76	310×10^{3}	<0.1		0.1		0.7	M^{s}		0.3^{h}			0.3		0.2	0.1^{h}	
M1-31	6-14-76	330×10^{3}	<0.1		0.7		0.6			0.7			<0.1	$<0.1^{j}$			
M1-32	6-15-76	320×10^{3}			<0.1	0.2	0.1			<0.1	<0.1	$<0.1^{k}$	M^{o}				
M1-33	6-15-76	280×10^{3}	<0.1		$<0.1^{o}$		0.1	0.4		0.2^{h}	<0.1	$<0.1^{k}$	$<0.1^{o}$				
M1-34	6-16-76	M^{o}					M^{o}	M^{o}	M^{o}	M^{o}	M^{o}		M^{o}				
M1-35	6-17-76	170×10^{3}	$<0.1^{k}$		1.8	$<0.1^{k}$	0.8			1.1	0.5^{j}		0.2^{k}	0.6			

Table F-7

POST-FAIR MICROBIOLOGICAL AEROSOL RUN COLIPHAGE CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Wastewater Sample (PFU/ℓ)	Aerosol Samples (PFU/m³ of air)							
			Upwind Sampler	Downwind Samplers - Perpendicular Distance from Wet Line Edge						
				50 m Left	50 m Right	100 m Left	100 m Right	Distant Samplers Left	Center	Right
M2-1	1-21-77	180 × 10³	<0.1^j	0.4	0.3	0.5	0.3	<0.1^h	<0.1	<0.1^j
M2-2	1-25-77	94 × 10³	<0.1^{h,j}	0.7	0.4	0.1	0.3	<0.1^h	<0.1^j	0.3^j
M2-3	1-25-77	160 × 10³	<0.1^j	0.8	0.4^j	0.1	0.3	M^g	<0.1	0.3
M2-4	1-30-77	120 × 10³	<0.1	0.8	0.7^j	<0.1	0.3	<0.1	0.1^m	<0.1
M2-5	1-30-77	170 × 10³	<0.1	0.4^h	0.1	0.3	0.9^{d,i}	<0.1	<0.1^m	<0.1
M2-6	2-9-77	M^g	M^g	M^g	M^g	M^g	M^g	M^g	M^g	M^g
M2-10	2-23-77	300 × 10³	<0.1	0.1	1.1	0.9^j	1.2^j	<0.1	<0.1	<0.1
M2-11	2-24-77	390 × 10³	<0.1	0.4	0.7	0.3	0.1	<0.1^j	<0.1	<0.1
M2-12	2-24-77	230 × 10³	<0.1	0.3	1.1	0.4	0.1	<0.1^j	0.4	0.3^d
M2-13	2-28-77	310 × 10³	<0.1	1.1	1.3	1.2^d	0.9^d	<0.1	<0.1	<0.1^{k,m}
M2-14	3-14-77	190 × 10³	<0.1	2.8	2.1	0.8^j	0.5	<0.1^j	<0.1	0.1
M2-15	3-16-77	120 × 10³	0.3	0.3	0.4	0.1	0.3	<0.1	<0.1^j	<0.1
M2-16	3-17-77	140 × 10³	<0.1	0.9	0.7	<0.1	1.1^i	<0.1^j	<0.1	<0.1
M2-17	3-18-77	190 × 10³	<0.1	0.5	0.5^h	0.1	0.4	<0.1	<0.1	0.1
M2-22	3-25-77	170 × 10³	<0.1	1.1	0.4	<0.1	0.1	<0.1	<0.1^j	<0.1
M2-23	3-26-77	380 × 10³	<0.1	0.3	<0.1	0.1	<0.1	<0.1	0.1	<0.1
M2-24	3-26-77	700 × 10³	<0.1	1.6	2.1	0.2^d	0.7^d	<0.1	<0.1	<0.1
M2-25	3-27-77	1200 × 10³	<0.1	2.5	2.2	0.7	0.3^d	<0.1	<0.1	<0.1^d
M2-26	3-27-77	930 × 10³	0.1^j	0.3	<0.1	<0.1	<0.1	<0.1^{k,p}	<0.1	<0.1^j
M2-29	4-11-77	400 × 10³	<0.1	0.7	0.4	<0.1^i	0.1	<0.1	<0.1^j	<0.2
M2-30	4-12-77	180 × 10³	<0.1	0.1	0.3	<0.1	0.3	0.5^l	0.5	<0.1
M2-31	4-13-77	240 × 10³	<0.1	0.8	0.8	0.8	0.1	<0.1	<0.1	<0.1
M2-32	4-14-77	240 × 10³	<0.1	0.8	0.4	<0.1	<0.1	<0.1	<0.2	<0.2
M2-33	4-19-77	450 × 10³	<0.1	0.3	<0.1	0.4	53	<0.1^j	<0.1	<0.1
M2-34	4-19-77	200 × 10³	<0.1	0.1	0.2^d	0.3^i	0.2	<0.1	<0.1	<0.1
M2-35	4-22-77	1200 × 10³	<0.1	2.6	2.8	1.1	1.1	<0.1	<0.1	137^k
M2-36	4-23-77	780 × 10³	<0.1	0.4	0.1	0.3^j	0.1	<0.1	<0.1	<0.1
M2-37	4-24-77	480 × 10³	<0.4^{d,i}	0.4	0.4	0.1	0.4	<0.2^m	<0.1	<0.1^d
M2-38	4-24-77	430 × 10³	<0.1	0.4	0.4	0.3	0.7	<0.1	<0.1	<0.1

Table F-8
PRE-FAIR MICROBIOLOGICAL AEROSOL RUN FECAL STREPTOCOCCI CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Aerosol Samples (CFU/m³ of air)														
		Upwind Sampler	Downwind Samplers Perpendicular Distance from Wet Line Edge													
			5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1[a]	5-4-76	<1[j]	<1[b,g]	<1		<1	<1[b]					<1		<1		
M1-2[a]	5-5-76	<1	<1[b,g]	<1		<1[c]	<1[b,h]					<1[i]		<1		
M1-3[a]	5-5-76	<1	<1	<1		<1[c]	<1[e]					<1		<1		
M1-4[a]	5-13-76	32	≥93[c]	≥62		37						≥100[b,d]		≥62		
M1-5[a]	5-13-76	0.4	18	29		37								6[i]		
M1-6	5-17-76	<3[j]	3	<3		3[b]						<5[e,h]		<3[h,j]		
M1-7	5-17-76	6	<3	<3[f,h]		3[e]						<3[h]		<3[h]		
M1-8	5-21-76	<0.6	<0.5	0.5		<0.7[j]	<0.7[h]					<0.6	0.5[h]			
M1-9	5-24-76	<0.6	6.0[g]	1.6		0.7						<0.6		0.5		
M1-10	5-24-76	<0.6		4.2		4.0	2.0[j]		2.7			4.7[h]		3.1[h]		
M1-11	5-25-76	0.6		3.1		5.7[c]	2.7		2.7			1.5[h]		28[h]		
M1-12	5-27-76	<0.3		15		30[c]	25[h]		M[q]			13		10[h]		
M1-13	5-27-76	0.3				1.3	1.7[h]					8.5[h]		0.6		7.0[j]
M1-14	5-27-76	<0.3				14						90		26		6.8[h]
M1-15	6-3-76	0.3		2.1		3.0	M[q]		2.8[h]			1.8		2.3	1.8[h]	
M1-31	6-14-76	1.5		3.3		1.9			3.3			3.2	2.1[j]			
M1-32	6-15-76			<0.3	<0.3	<0.3			0.3	1.2	<0.3	M[o]				
M1-33	6-15-76	<0.3		0.3[n]		0.5	0.3		0.7[b]	<0.3	1.1	≤0.3[o]				
M1-34	6-16-76	0.6				0.8	1.8[j]	4.3	5.1	1.2		≥11				
M1-35	6-17-76	0.3		4.7	4.4	2.7			2.4	3.3[j]		6.5	2.4			

Table F-9
POST-FAIR MICROBIOLOGICAL AEROSOL RUN FECAL STREPTOCOCCI CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Wastewater Sample (CFU/100 ml)	Aerosol Samples (CFU/m^3 of air)							
				Downwind Samplers - Perpendicular Distance from Wet Line Edge						
								Distant Samplers		
			Upwind Sampler	50 m Left	50 m Right	100 m Left	100 m Right	Left	Center	Right
M2-1	1-21-77	9.7 × 10^5	0.5[j]	1.0	1.0	1.8	0.4	0.4[h]	1.9	0.3[j]
M2-2	1-25-77	4.8 × 10^6	3.3[hj]	1.4	0.4	0.9	0.7	0.7[h]	0.4[j]	0.3[j]
M2-3	1-25-77	1.3 × 10^6	2.7[j]	3.3	7.7[j]	8.3	7.3	M[s]	3.7	1.5
M2-4	1-30-77	6.0 × 10^5	0.3	1.0	0.7[j]	0.4	0.1	<0.1	0.3[m]	0.3
M2-5	1-30-77	12.0 × 10^5	0.3	1.3[h]	1.3	1.0	1.1[di]	0.3	0.5[m]	0.2
M2-6	2-9-77	3.3 × 10^5	1.0[m]	0.4	0.4	0.2	0.6	0.2	0.1	0.1
M2-10	2-23-77	2.0 × 10^5	1.6	0.1	0.4	0.4[j]	0.4[i]	0.4	1.1	0.3
M2-11	2-24-77	0.23 × 10^5	<0.1	<0.1	5.2[k]	<0.1	0.1	0.4[j]	0.3	<0.1
M2-12	2-26-77	1.2 × 10^5	<0.1[j]	<0.1	107	1.1	0.4	0.2[j]	<0.1	<0.1[d]
M2-13	2-28-77	5.7 × 10^5	0.1	0.4	2.1	0.8[d]	0.6[d]	0.6	0.1	0.1[Lm]
M2-14	3-14-77	2.0 × 10^5	0.1	<0.1	0.6	0.4[j]	0.7	<0.1[j]	0.1	<0.1
M2-15	3-16-77	7.0 × 10^5	<0.1	0.1	0.2	0.6	0.1	<0.1	<0.1[j]	0.1
M2-16	3-17-77	12.0 × 10^5	<0.1	0.8	0.8	0.2	0.4[i]	<0.1[j]	0.1	<0.1
M2-17	3-18-77	7.2 × 10^5	<0.1	0.6	0.3[h]	0.8	0.4	0.8	<0.1	2.4
M2-22	3-25-77	4.3 × 10^5	0.1	0.4	<0.1	<0.1	<0.1	<0.1	<0.1[j]	<0.1
M2-23	3-26-77	5.7 × 10^5	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
M2-24	3-26-77	10.0 × 10^5	<0.1	0.2	0.4	0.3[d]	0.6[d]	0.1	0.1	<0.1
M2-25	3-27-77	11.0 × 10^5	<0.1	0.7	0.9	<0.1	0.2[d]	<0.1	<0.1	0.1[d]
M2-26	3-27-77	7.0 × 10^6	<0.1[j]	<0.1	<0.1	<0.1	<0.1	<0.1[jp]	<0.1	<0.1[i]
M2-29	4-11-77	4.3 × 10^5	<0.1	<0.1	<0.1	0.7[i]	<0.1	<0.1	0.1	<0.1
M2-30	4-12-77	3.8 × 10^5	0.2	<0.1	0.3	0.1	<0.1	<0.1[l]	<0.1	1.4
M2-31	4-13-77	6.2 × 10^5	0.6	1.0	0.7	3.7	1.8	1.9	0.4	0.8
M2-32	4-14-77	3.0 × 10^5	0.1	0.1	0.6	0.2	<0.1	0.2	0.4	0.2
M2-33	4-19-77	2.2 × 10^5	<0.1	0.1	<0.1	0.2	<0.1	<0.1[j]	<0.1	<0.1
M2-34	4-19-77	1.9 × 10^5	0.3	0.3	0.5[d]	18.0[j]	0.3	0.3	0.5	0.3
M2-35	4-22-77	0.63 × 10^5	<0.1	4.3	0.2	0.1	0.3	<0.1	<0.1	<0.1
M2-36	4-23-77	3.0 × 10^5	0.3	0.3	0.3	0.1[j]	<0.1	1.7	0.1	0.1
M2-37	4-24-77	1.6 × 10^5	<0.1[di]	0.6	0.6	0.2	<0.1	0.2[m]	0.2	<0.1[d]
M2-38	4-24-77	0.93 × 10^5	0.2	4.9	5.1	1.6	7.0	0.1	0.2	<0.1

Table F-10
PRE-FAIR MICROBIOLOGICAL AEROSOL RUN PSEUDOMONAS CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Aerosol Samples (CFU/m³ of air)														
		Upwind Sampler	Downwind Samplers Perpendicular Distance from Wet Line Edge													
			5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1	5-4-76	+	+	+		+	+					+		+		
M1-2	5-5-76	+	+	+		+	+					+		+		
M1-3	5-5-76	+	+	+		+	+					+		+		
M1-4	5-13-76	<15	190^{c}	13		33						M^{s}		51		
M1-5	5-13-76	1500	140	1300		330								$M^{i,s}$		
M1-6	5-17-76	89^{j}	430	750		$<17^{b}$						$<24^{e,h}$		$77^{h,j}$		
M1-7	5-17-76	<15	4900	$2300^{h,f}$		380^{e}						M^{t}		77^{h}		
M1-8	5-21-76	15	240	290		470^{j}	$<17^{h}$					<15	$<13^{h}$			
M1-9	5-24-76	<15	140^{g}	52		<17						74		<13		
M1-10	5-24-76	<15		570		≥5300	33^{j}		150			220^{h}		210^{h}		
M1-11	5-25-76	300		M^{t}		3100^{c}	83		68			100^{h}		30^{h}		
M1-12	5-27-76	<15		290		$<24^{c}$	$<17^{h}$		M^{q}			<13		$<15^{h}$		
M1-13	5-27-76	<15				330	$<17^{h}$					230^{n}		15		310^{j}
M1-14	5-27-76	<15				2200						17000		1800		20000^{k}
M1-15	6-3-76	<9		<9		<10	M^{q}		50^{h}			8		19	$<9^{h}$	
M1-31	6-14-76	<9		<9		19			8			9	9^{j}			
M1-32	6-15-76			8	<9	<9			<8	<9	120000	M^{o}				
M1-33	6-15-76	<9		$<9^{n}$		<8	9		$<11^{b}$	<9	52000	$<9^{o}$				
M1-34	6-16-76	15				91	$TNTC^{k}$	76	180	100		3600				
M1-35	6-17-76	<14		250	M^{t}	210			100	260^{j}		89	61			

Table F-11
POST-FAIR MICROBIOLOGICAL AEROSOL RUN MYCOBACTERIA CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Wastewater Sample (CFU/100 ml)	Aerosol Samples (CFU/m^3 of air)							
			Upwind Sampler	Downwind Samplers–Perpendicular Distance from Wet Line Edge						
				50 m Left	50 m Right	100 m Left	100 m Right	Distant Samplers Left	Distant Samplers Center	Distant Samplers Right
M2-1	1-21-77	18.0×10^5	$<11^{j}$	<11	<11	<11	<11	$<11^{h}$	<11	$<11^{j}$
M2-2	1-25-77	6.6×10^5	$<11^{h,j}$	<11	<11	<11	<11	$<11^{h}$	$<11^{j}$	$<11^{j}$
M2-3	1-25-77	9.0×10^5	$<11^{j}$	<11	$<11^{j}$	<11	<11	M^{s}	<11	<11
M2-4	1-30-77	5.7×10^6	<11	<11	22^{j}	<11	<11	<11	$<11^{m}$	<11
M2-5	1-30-77	6.6×10^5	<11	$<11^{h}$	<11	<11	$<9^{d,j}$	<11	$<11^{m}$	<11
M2-6	2-9-77	10.0×10^6	$<11^{m}$	<11	<11	<11	<11	<11	<11	<11
M2-10	2-23-77	5.6×10^6	<11	<11	<11	$<11^{j}$	$<11^{i}$	<11	<11	<11
M2-11	2-24-77	6.0×10^6	<11	<11	<11	<11	<11	$<11^{j}$	<11	<11
M2-12	2-24-77	3.5×10^6	$<11^{j}$	<11	<11	<11	<11	$<11^{j}$	<11	$<11^{d}$
M2-13	2-28-77	5.0×10^6	<11	<11	<11	$<9^{d}$	9^{d}	<11	<11	$<11^{l,m}$
M2-14	3-14-77	3.6×10^6	$<11^{k}$	<11	<11	$<11^{j,k}$	11	$<11^{j}$	<11	<11
M2-15	3-16-77	11.0×10^5	<11	11	11	<11	<11	<11	$<11^{j}$	<11
M2-16	3-17-77	3.0×10^5	$\leq 17^{k}$	$<17^{k}$	<11	$<30^{k}$	M^{t}	$<17^{j,k}$	<11	$<17^{k}$
M2-17	3-18-77	2.5×10^5	$<17^{k}$	$<17^{k}$	$<11^{h}$	$<30^{k}$	<11	<11	$<30^{k}$	<11
M2-22	3-25-77	1.0×10^6	<11	<11	<11	<11	<11	<11	$<17^{j}$	<11
M2-23	3-26-77	2.0×10^5	<11	<11	<11	<11	<11	<17	<11	<11
M2-24	3-26-77	3.0×10^6	<11	<11	<11	$<9^{d}$	$<17^{d}$	<11	<11	<11
M2-25	3-27-77	1.0×10^5	<11	<17	<11	<11	$<12^{d}$	<11	<11	$<12^{d}$
M2-26	3-27-77	3.0×10^5	$<30^{j}$	<11	<11	<11	<11	$\underline{<11^{j,p}}$	<11	$<11^{j}$
M2-29	4-11-77	1.0×10^5	0.7	2.0	0.3	1.3^{i}	<0.3	0.7	$<0.3^{j}$	0.7
M2-30	4-12-77	10.0×10^5	<0.3	<0.3	0.3	0.3	0.7	2.3^{i}	1.3	1.7
M2-31	4-13-77	5.0×10^5	0.3	0.7	0.3	1.7	1.0	0.7	0.7	0.3
M2-32	4-14-77	7.0×10^5	<0.3	0.3	2.3	2.0	1.0	0.7	1.3	<0.3
M2-33	4-19-77	7.5×10^5	<0.3	2.3	1.0	<0.3	<0.3	0.3^{j}	1.3	0.7
M2-34	4-19-77	7.6×10^5	<0.3	<0.3	0.8^{d}	1.7^{i}	1.0	1.7	1.0	0.3
M2-35	4-22-77	1.0×10^5	0.7	4.3	2.7	1.0	0.7	<0.3	<0.3	1.0
M2-36	4-23-77	6.0×10^5	<0.3	1.7	0.7	1.0^{j}	-1.0	<0.3	<0.3	1.0
M2-37	4-24-77	7.3×10^5	$2.0^{d,i}$	1.0	1.3	1.3	<11	$<0.3^{m}$	0.3	0.4^{d}
M2-38	4-24-77	5.0×10^5	$<11^{k}$	11^{k}	11^{k}	$<11^{k}$	$<11^{k}$	$<11^{k}$	$<11^{k}$	$<11^{k}$

Table F-12

PRE-FAIR MICROBIOLOGICAL AEROSOL RUN CLOSTRIDIUM PERFINGENS CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Aerosol Samples (MPN/m^3 of air)														
		Upwind Sampler	Downwind Samplers - Perpendicular Distance from Wet Line Edge													
			5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1	5-4-76	+	+	+		+	>0.1^{h}					+		+		
M1-2	5-5-76	≥0.3	≥2.7^{b,d}	≥0.3		≥3.7^{c}	≥3.3^{b,h}					≥0.3^{i}		≥0.3		
M1-3	5-5-76	≥0.3	≥2.7	≥0.3		≥3.7^{c}	≥3.3^{e}					≥3.0		≥2.6		
M1-4	5-13-76	<0.9	<1.2^{c}	<0.8		<1.0						<1.3^{b,d}		2.3		
M1-5	5-13-76	<0.9	5.1	6.0		3.0								5.9^{j}		
M1-6	5-17-76	<0.9^{j}	2.4	1.0		1.3^{h}						$\underline{36^{e,h}}$		2.3^{h,j}		
M1-7	5-17-76	<0.9	2.4	$\underline{8.6^{f,h}}$		<1.0^{g}						$\underline{7.7^{h}}$		2.3^{h}		
M1-8	5-21-76	<0.9	0.8	<0.8		5.0^{j}	3.0^{h}					1.2	0.8^{h}			
M1-9	5-24-76	<0.9	1.9^{d}	1.8		1.3						<0.9		<0.8		
M1-10	5-24-76	<0.9		2.5		3.0	1.3^{j}		1.9			2.1^{h}		<0.8^{h}		
M1-11	5-25-76	<0.9		1.0		1.9^{c}	<1.0		<0.8			1.0^{h}		4.4^{h}		
M1-12	5-27-76	<0.9		2.3		3.3^{c}	5.0^{h}		M^{q}			1.0		<0.9^{h}		
M1-13	5-27-76	<0.9				1.3	2.3^{h}					1.0^{h}		<0.9		1.8^{j}
M1-14	5-27-76	<0.9				1.3						2.3		0.9		<0.8^{h}
M1-15	6-3-76	<0.9		0.9		1.3	M^{q}		1.1^{h}			1.0		<0.8	<0.9^{h}	
M1-31	6-14-76	0.9		2.7		1.9			<0.8			1.2	1.2^{j}			
M1-32	6-15-76			<0.8	<0.9	<0.9			<0.8	<0.9	<0.8	M^{o}				
M1-33	6-15-76	<0.9		$\underline{<0.9^{n}}$		<0.8	<0.9		<1.1^{h}	<0.9	M^{t}	$\underline{<0.9^{o}}$				
M1-34	6-16-76	<0.9				<0.8	M^{t}	M^{t}	M^{t}	M^{t}		M^{t}				
M1-35	6-17-76	M^{t}		M^{t}	M^{t}	M^{t}			M^{t}	M^{t}		M^{t}	M^{t}			

Table F-13
PRE-FAIR MICROBIOLOGICAL AEROSOL RUN KLEBSIELLA CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Aerosol Samples (CFU/m³ of air)														
		Upwind Sampler	Downwind Samplers Perpendicular Distance from Wet Line Edge													
			5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1	5-4-76	$<5^{j}$	$<5^{b,g}$	<4		<6	$<6^{b}$					<5		<4		
M1-2	5-5-76	<5	$<5^{b,g}$	<4		$<6^{c}$	$<6^{b,h}$					$<5^{i}$		<4		
M1-3	5-5-76	<5	<5	<4		$<6^{c}$	$<6^{e}$					<5		<4		
M1-4	5-13-76	<5	$<7^{c}$	<4		<6						$<7^{b,d}$		<4		
M1-5	5-13-76	<5	<7	<4		<6								$<4^{i}$		
M1-6	5-17-76	$<5^{j}$	<5	<4		$<6^{b}$						$<8^{e,h}$		$<4^{h,j}$		
M1-7	5-17-76	<5	<5	$<6^{h,f}$		$<6^{e}$						$<6^{h}$		$<4^{h}$		
M1-8	5-21-76	<5	5	<4		$<6^{j}$	$<6^{h}$					<5	$<4^{h}$			
			ozanae													
M1-9	5-24-76	<5	$<5^{g}$	<4		<6						<5		<4		
M1-10	5-24-76	<5		<4		<6	$<6^{j}$		<5			5^{h}		$<4^{h}$		
												ozanae				
M1-11	5-25-76	<5		<4		$<8^{c}$	<6		<5			$<4^{h}$		$<5^{h}$		
M1-12	5-27-76	<5		<4		13^{c}	$<6^{h}$		M^{q}			<4		$<5^{h}$		
						pneumoniae										
M1-13	5-27-76	<5				<6	$<6^{h}$					$<4^{h}$		<5		$<4^{j}$
M1-14	5-27-76	<5				<6						4		<5		$<4^{h}$
												ozanae				
M1-15	6-3-76	<5		<5		<6	M^{q}		$<5^{h}$			<4		<4	$<4^{h}$	
M1-31	6-14-76	<5		<5		<5			$<4^{j}$			<5	$<5^{j}$			
M1-32	6-15-76			<4	<5	<5			<4	<5	<5	M^{o}				
M1-33	6-15-76	<5		$\underline{<5^{n}}$		<4	<5		$<6^{b}$	<5	<5	$\underline{<5^{o}}$				
M1-34	6-16-76	<5				<4	$<4^{j}$	<5	<5	<5		<5				
M1-35	6-17-76	<5		<4	<5	<5			<5	$<4^{j}$		<5	<5			

Table F-14

PRE-FAIR MICROBIOLOGICAL AEROSOL RUN 3-DAY ENTEROVIRUS PLAQUE CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No.	Run Date	Aerosol Samples (PFU/m^3 of air)														
		Upwind Sampler	Downwind Samplers Perpendicular Distance from Wet Line Edge													
			5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1	5-4-76	<0.2[j]	<0.2[b,g]	<0.2		<0.3	<0.3[b]					<0.2		<0.2		
M1-2	5-5-76	<0.2	<0.2[b,g]	<0.2		<0.3[c]	<0.3[b,h]					<0.2[i]		<0.2		
M1-3	5-5-76	<0.2	<0.2	<0.2		<0.3[c]	<0.3[e]					<0.2		<0.2		
M1-4	5-13-76	<0.2	<0.3[c]	<0.2		<0.3						<0.3[b,g]		<0.2		
M1-5	5-13-76	<0.2	<0.3	<0.2		<0.3								<0.2[i]		
M1-6	5-17-76	<0.2[j]	<0.2	<0.2		<0.3[h]						<0.4[e,h]		<0.2[h,j]		
M1-7	5-17-76	<0.2	<0.2	<0.3[f,h]		<0.3[e]						<0.3[h]		<0.2[h]		
M1-8	5-21-76	<0.2	<0.2	<0.2		<0.3[i]	<0.3[h]					<0.2	<0.2[h]			
M1-9	5-24-76	<0.2	<0.2[g]	<0.2		<0.3						<0.2		<0.2		
M1-10	5-24-76	<0.2		<0.2		<0.3	<0.3[i]		<0.2			<0.2[h]		<0.2[h]		
M1-11	5-25-76	<0.2		<0.2		<0.4[c]	<0.3		<0.2			<0.2[h]		<0.2[h]		
M1-12	5-27-76	<0.2		<0.2		<0.3[c]	<0.3[h]		M[q]			<0.2		<0.2[h]		
M1-13	5-27-76	<0.2				<0.3	<0.3[h]					<0.2[h,k]		<0.2[k]		<0.2[j,k]
M1-14	5-27-76	<0.2[k]				<0.3[k]						<0.2[k]		<0.2[h]		<0.2[h,k]
M1-15	6-3-76	<0.2		<0.2		<0.3	M[q]		<0.2[h]			<0.2		<0.2	<0.2[h]	
M1-31	6-14-76	<0.2		<0.2[k]		<0.2[k]			<0.2[k]			<0.2	<0.2[j]			
M1-32	6-15-76			<0.2	<0.2	<0.2			<0.2	<0.2	<0.2	M				
M1-33	6-15-76	<0.2		<0.2[n]		<0.2	<0.2		<0.3[b]	<0.2	<0.2[k]	<0.2[n]				
M1-34	6-16-76	<0.2				M[f]	<0.2[j]	<0.2	<0.2	<0.2		<0.2				
M1-35	6-17-76	<0.2		<0.2[k]	<0.2	<0.2[k]			<0.2	<0.2[j,k]		<0.2	<0.2			

Table F-15
PRE-FAIR MICROBIOLOGICAL AEROSOL RUN 5-DAY ENTEROVIRUS PLAQUE CONCENTRATIONS BY SAMPLER DISTANCE

Aerosol Run No	Run Date	Aerosol Samples (PFU/m³ of air)														
		Upwind Sampler	Downwind Samplers Perpendicular Distance from Wet Line Edge													
			5 m	10 m	10 m	20 m	20 m	20 m	30 m	40 m	40 m	50 m	50 m	100 m	100 m	200 m
M1-1	5-4-76	$<0.2^{j}$	$<0.2^{h,g}$	<0.2		<0.3	$<0.3^{b}$					$<0.2^{h}$		<0.2		
M1-2	5-5-76	<0.2	$<0.2^{h,g}$	<0.2		$<0.3^{c}$	$<0.3^{b,h}$					$<0.2^{i}$		<0.2		
M1-3	5-5-76	<0.2	<0.2	<0.2		$<0.3^{c}$	$<0.3^{e}$					<0.2		<0.2		
M1-4	5-13-76	<0.2	$<0.3^{c}$	<0.2		<0.3						$<0.3^{b,d}$		<0.2		
M1-5	5-13-76	<0.2	<0.3	<0.2		<0.3								$<0.2^{i}$		
M1-6	5-17-76	$<0.2^{j}$	<0.2	<0.2		$<0.3^{b}$						$<0.4^{c,h}$		$<0.2^{h,d}$		
M1-7	5-17-76	<0.2	<0.2	$<0.3^{f,h}$		$<0.3^{e}$						$<0.3^{h}$		0.2^{h}		
M1-8	5-21-76	<0.2	<0.2	<0.2		$<0.3^{j}$	$<0.3^{h}$					<0.2	$<0.2^{h}$			
M1-9	5-24-76	<0.2	$<0.2^{g}$	0.2		<0.3						<0.2		<0.2		
M1-10	5-24-76	<0.2		<0.2		<0.3	$<0.3^{j}$		<0.2			$<0.2^{h}$		$<0.2^{h}$		
M1-11	5-25-76	<0.2		<0.2		$<0.4^{c}$	<0.3		<0.2			$<0.2^{h}$		$<0.2^{h}$		
M1-12	5-27-76	0.5		<0.2		$<0.3^{c}$	$<0.3^{h}$		M^{q}			<0.2		$<0.2^{h}$		
M1-13	5-27-76	<0.2				$<0.3^{k}$	$<0.3^{h}$					$<0.2^{h,k}$		$<0.2^{k}$		$<0.2^{j,k}$
M1-14	5-27-76	$<0.2^{k}$				$<0.3^{k}$						$<0.2^{h,k}$		$<0.2^{k}$		$<0.2^{h,k}$
M1-15	6-3-76	<0.2		<0.2		<0.3	M^{q}		$<0.2^{h}$			<0.2		<0.2	$<0.2^{h}$	
M1-31	6-14-76	<0.2		$<0.2^{k}$		$<0.2^{k}$			$<0.2^{k}$			<0.2	$<0.2^{j}$			
M1-32	6-15-76			<0.2	<0.2	<0.2			<0.2	<0.2	<0.2	M^{o}				
M1-33	6-15-76	<0.2		$<0.2^{n}$		<0.2	<0.2		$<0.3^{b}$	<0.2	$<0.2^{k}$	$<0.2^{o}$				
M1-34	6-16-76	<0.2				M^{l}	$<0.2^{j}$	<0.2	<0.2	<0.2		<0.2				
M1-35	6-17-76	<0.2		$<0.2^{k}$	<0.2	$<0.2^{k}$			<0.2	$<0.2^{j,k}$		<0.2	<0.2			

FOOTNOTES FOR UNUSUAL EVENTS

Footnotes	
a	MPN method used instead of normal assay method.
b	Excessive sampler arcing observed; no data adjustment made.
c	Data adjusted for extreme sampler arcing.
d	Data adjusted for nonstandard volume of air sampled.
e	Data adjusted for sampler power supply problems.
f	Data adjusted for loss of BHI sampler fluid by means other than evaporation.
g	Possible sample contamination; too close to spray line.
h	Possible sample contamination; loss or foaming over of BHI.
i	Possible sample contamination; equipment malfunction (pump/hose readjustment, open top, tubing problems).
j	Possible sample contamination; external sources (vehicle traffic, train dust, wind shift, insects, smoke bomb, cattle too close, operator upwind).
k	Possible sample contamination observed by analysis laboratory.
l	Probable sample contamination; external source (nearby truck or dirt road).
m	Probable sample contamination; equipment malfunction (glass view on plate broken, top opened, tubing broken, contaminated intake).
n	Certain sample contamination; improper cleaning procedures (clorox residual left).
o	Certain sample contamination; improper collection procedures used.
p	Certain sample contamination; sample dropped.
q	No sample collected because sampler developed problems during the run.
r	Sample amount was insufficient for analysis.
s	No analysis performed.
t	No analysis result reported because laboratory observed sample contamination.
u	Analysis results lost.
v	Elevated sample temperature after shipment (8-9°).

value — Sample contamination affecting result inferred.

APPENDIX G
PRELIMINARY ANALYSES OF FACTORS AFFECTING AEROSOL LEVELS

APPENDIX G
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APPENDIX G

1. Preliminary Evaluation of Distance and Solar Radiation Factors

a. *Analysis of Variance*

This section examines whether the spray line is a significant source of each microorganism group, and if it is, whether the downwind microorganism concentration depends upon distance from the spray line, and the level of solar radiation. If the spray line is not a significant source, the microorganism concentration at the various sampled distances on the Post-Fair runs should be approximately equal. This establishes the null hypothesis which may be stated as:

$$H_0: C_{upwind} = C_{50m} = C_{100m} = C_{distant}, \; C_x = \text{microorganism concentration at a given distance.}$$

However, if the spray is a source of the microorganisms, there should be a significant increase in concentration at the close downwind (50 meters) distance over the upwind levels. If microorganism mortality increases, or conversely, if microorganism concentration decreases, with distance or aerosol age, there should be a significant decrease in concentration at far downwind distances. The microorganism concentrations at intermediate distances should be less than those at the close downwind distances but greater than those at the far downwind distances, if the two conditions above are true.

This section examines the appropriateness of constructing a microbiological dispersion model. The problem to be considered is whether or not the data conform to a model which characterizes source and distance factors. First, it must be determined that the spray line is a source of the microorganisms. This is done by measuring microorganism levels that are significantly higher at some distance downwind from the spray line than those at some background or upwind location; if the downwind levels are not significantly higher, then the spray line is not necessarily a source. If the spray line is shown to be a source, distance factors should also be analyzed. It would be expected that microbiological aerosol levels decrease as distance from the spray line increases. The close downwind levels used to determine whether the spray line is a source are compared to levels measured at some distance farther downwind. If those close downwind levels are significantly higher than the distant downwind levels, increased distance (or aerosol age) can be considered to be a factor in a microbiological dispersion model. This establishes the alternative hypothesis which may be stated as:

$$H_1: C_{50m} > C_{100m} > C_{distant} \geq C_{upwind}$$

To test these hypotheses, an analysis of variance (ANOVA) of the natural log transformed concentrations is used. The logarithm transformation makes the assumptions of constant error variance and normality more tenable. For this analysis there are two factors: distance and solar radiation. The factors are broken into levels; distance has four levels: upwind, 50 meters, 100 meters, and distant; solar radiation has two levels: high and low. Distance was selected in place of aerosol age as a factor because four fixed levels of distance were established by the Post-Fair sampler design. The levels of solar radiation were established by calculating the mean of solar radiation measurements from the Post-Fair meteorological data; fourteen runs are below that mean, fifteen are above. The linear model for the analysis of variance is given in Table G-1. The nature of the data dictates the design of the analysis of variance; this particular study is a two-factor experiment with repeated measures on the distance factor (mixed or between-within design, see Table G-2). This

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Table G-1
LINEAR MODEL FOR TWO FACTOR ANOVA WITH REPEATED MEASURES ON ONE FACTOR

$$X_{ijk} = \mu + \alpha_i + \pi_{k(i)} + \beta_j + \alpha\beta_{ij} + \beta\pi_{jk(i)} + \varepsilon_{m(ijk)}$$

X_{ijk} = microbiological concentration

μ = microbiological concentration population mean

α_i = main effect of level a_i of factor A (solar radiation)

$\pi_{k(i)}$ = effect of runs within levels of solar radiation

β_j = main effect of level b_j of factor B (distance)

$\alpha\beta_{ij}$ = interaction of main effects

$\beta\pi_{jk(i)}$ = main effect of level b_j of distance factor by runs within solar radiation factors

$\varepsilon_{m(ijk)}$ = experimental error

i = levels of solar radiation (low and high)

j = levels of distance (upwind, 50 m, 100 m, distant downwind)

k = individual Post Fair runs

Table G-2

SUMMARY OF ANALYSIS OF VARIANCE WITH EXPECTED VALUE OF MEAN SQUARE

Source of Variation	df	E(MS)
Between Subjects	np-1	
A (Solar Radiation)	p-1	$\sigma_\varepsilon^2 + q\sigma_\pi^2 + nq\sigma_\alpha^2$
Subjects Within Groups (Runs Within Solar Radiation	p(n-1)	$\sigma_\varepsilon^2 + q\sigma_\pi^2$
Within Subjects	np(q-1)	
B (Distance)	q-1	$\sigma_\varepsilon^2 + \sigma_{\beta\pi}^2 + np\sigma_\beta^2$
AB (Solar Radiation Distance Interaction)	(p-1)(q-1)	$\sigma_\varepsilon^2 + \sigma_{\beta\pi}^2 + n\sigma_{\alpha\beta}^2$
B x Subjects Within Groups (Distance By Runs Within Solar Radiation)	p(n-1)(q-1)	$\sigma_\varepsilon^2 + \sigma_{\beta\pi}^2$

p = number of levels of solar radiation
q = number of levels of distance
n = number of runs per cell

is properly a repeated measures design because a particular run occurs at only one level of solar radiation (i.e., runs between levels of solar radiation), and at all levels of distance (i.e., runs within levels of distance). There are two assumptions associated with this design and the interpretation of its results. The first is that the factors of distance and solar radiation have fixed effects. This implies that any conclusions derived from the study are applicable only to the levels included in the study. The second is runs have random effects; this implies that they are representative of any run that can be made under the conditions imposed by the factors involved in the design.

The results from the calculation of analysis of variance determine not only if the factors, (distance and solar radiation) have a significant effect on microorganism aerosol levels, but also if their interaction has a significant effect on microorganism level. Analysis of variance does not, however, indicate which level or levels of the factors, if there is a significant effect, causes that effect; it only indicates that differences in levels or treatments of a factor vary significantly. Contrasts can be calculated to determine significant differences between treatment means at all levels of the analysis of variance or t-tests can be calculated for paired comparisons to detect differences in paired samples; these will be discussed later.

The particular factors used in the analysis of variance, distance, and solar radiation were chosen for several reasons. Distance is a factor because it is available at fixed levels in the Post-Fair design. Aerosol age is probably better related to microbiological die-off through exposure to a hostile environment. However, because aerosol age does not possess fixed levels in the design, its surrogate (distance) has been substituted. Solar radiation has been included as the environmental factor to categorize the runs because preceding studies have suggested that solar radiation may substantially reduce the microorganism concentration. It should be noted that although solar radiation was chosen for the ANOVA design, other environmental factors can and probably do affect microbiological aerosol concentration.

Our objective here is simply to investigate whether environmental factors effect the various microbiological factors in different ways. Since solar radiation is a known important environmental factor, evidence of its differential effects would be sufficient to motivate the separate development of tailored environmentally related models for each microorganism group. In addition, the inclusion of such other factors in the ANOVA would have led to an extremely complex design with little statistical power and results which would have been difficult to interpret.

With the following exceptions, the data of Appendix F were used in the analysis. If the upwind sample is underlined (denoting contamination), that run was deleted. If both members of a downwind sample pair at a given distance are underlined that run was deleted. If one member of a downwind sample pair at a given distance is underlined, that sample was deleted and only the remaining sample was used. If a run has missing data for the upwind sample or for both members of a downwind sample, that run was deleted. Some of the distant downwind samples were not considered to be downwind from the spray line (according to the meteorological data sheets); those samples were deleted from the analysis. If a concentration was below the detection limit, half the detection limit was substituted. If one level of solar radiation had more runs than the other, runs were randomly deleted until equal cell size was achieved. This was done because the computer program used (BMDO8V) demands equal cell size. For mycobacteria, only nine runs (M2-29 to M2-37) had most samples above the detection limit; these were the runs used for the analysis. Because there was little data to use, it was decided to divide the nine runs into three levels of solar radiation rather than two to avoid deleting more data.

The results are given in Tables G-3 through G-7. The tables give the sum of squares, their degrees of freedom, the mean squares, the F ratios, and, if the F ratio is significant, its probability. Also given, below the source table, are the geometric means for each cell in the ANOVA design. When there is a significant effect, the cell means give an indication where the variance occurs. If solar radiation has an effect,

Table G-3
ANALYSIS OF VARIANCE - LN (STANDARD PLATE COUNT AEROSOL CONCENTRATION)

Source of Variation	SS	df	MS	F	P
Between	82.494	19			
Solar Radiation	46.0425	1	46.0425	22.7359	<0.0005
Runs Within Solar Radiation	36.4515	18	2.0251		
Within	45.0831	60			
Distance	4.4556	3	1.4852	2.1028	
Solar Radiation-Distance	2.4885	3	0.8295	1.1744	
Distance by Runs Within Solar Radiation	38.1390	54	0.7063		
Total	127.5771	79			

CELL MEANS

	Distance			
Solar Radiation	Upwind	50 m	100 m	Distant
Low	580	1300	820	670
High	110	190	170	260

Table G-4
ANALYSIS OF VARIANCE - LN (TOTAL COLIFORM AEROSOL CONCENTRATION)

Source of Variation	SS	df	MS	F	P
Between	45.8092	23			
Solar Radiation	17.4362	1	17.4362	13.5196	<0.005
Runs Within Solar Radiation	28.3730	22	1.2897		
Within	217.4977	72			
Distance	157.6429	3	52.5476	62.5865	<0.0005
Solar Radiation-Distance	4.4437	3	1.4812	1.7642	
Distance by Runs Within Solar Radiation	55.4111	66	0.8396		
Total	263.3069	95			

CELL MEANS

	Distance			
Solar Radiation	Upwind	50 m	100 m	Distant
Low	0.15	5.80	1.22	0.19
High	0.10	1.53	0.36	0.12

Note: Detection Limit is 0.2

Table G-5
ANALYSIS OF VARIANCE - LN (COLIPHAGE AEROSOL CONCENTRATION)

Source of Variation	SS	df	MS	F	P
Between	10.7612	25			
Solar Radiation	0.2875	1	0.2875	0.6588	
Runs Within Solar Radiation	10.4737	24	0.4364		
Within	126.5376	78			
Distance	93.7108	3	38.2369	79.9511	<0.0005
Solar Radiation-Distance	4.6954	3	1.5651	4.0059	<0.025
Distance by Runs Within Solar Radiation	28.1314	72	0.3907		
Total	137.2988	103			

CELL MEANS

	Distance			
Solar Radiation	Upwind	50 m	100 m	Distant
Low	0.05	0.58	0.37	0.06
High	0.07	0.51	0.17	0.07

Note: Detection Limit is 0.1.

Table G-6
ANALYSIS OF VARIANCE - LN (FECAL STREPTOCOCCI AEROSOL CONCENTRATION)

Source of Variation	SS	df	MS	F	P
Between	127.8912	27			
Solar Radiation	55.6175	1	55.6175	20.0077	<0.0005
Runs Within Solar Radiation	72.2737	26	2.7798		
Within	71.5971	84			
Distance	13.0116	3	4.3372	5.8817	<0.005
Solar Radiation-Distance	1.0684	3	0.3561	0.4829	
Distance by Runs Within Solar Radiation	57.5171	78	0.7374		
Total	199.4883	111			

CELL MEANS

	Distance			
Solar Radiation	Upwind	50 m	100 m	Distant
Low	0.30	0.81	0.72	0.35
High	0.09	0.17	0.14	0.10

Note: Detection Limit is 0.1.

Table G-7
ANALYSIS OF VARIANCE - LN (MYCOBACTERIA AEROSOL CONCENTRATION)

Source of Variation	SS	df	MS	F	P
Between	4.3229	8			
Solar Radiation	2.7630	2	1.3815	5.3134	< 0.05
Runs Within Solar Radiation	1.5599	6	0.2600		
Within	28.1703	27			
Distance	6.6386	3	2.2129	3.3935	< 0.05
Solar Radiation-Distance	9.7933	6	1.6322	2.5029	0.06
Distance by Runs Within Solar Radiation	11.7384	18	0.6521		
Total	32.4932	35			

CELL MEANS

	Distance			
Solar Radiation	Upwind	50 m	100 m	Distant
Low	0.19	0.68	0.65	1.06
Medium	0.15	0.76	0.42	1.14
High	0.99	1.67	1.28	0.33

Note: Dectection Limit is 0.3.

simple inspection of the cell means (if there are only two levels) will indicate microbiological group concentration levels for the differing levels of solar radiation and, therefore, how increased solar radiation effects the microbiological parameters. However, the same procedure is not sufficient for locating the variation in the different levels of distance; as mentioned above, pair comparisons (t-test or a signed rank test) or contrasts are used for this purpose. For this analysis, t-tests or a signed rank test are used rather than contrasts; contrasts compare cell means whereas paired comparison tests compare the appropriate pairs.

All five of the microorganism groups are significantly affected by at least one of the factors. Solar radiation has a significant effect ($F = 22.74$; $df = 1, 18$; $P < 0.0005$) on standard bacterial plate count; distance and distance-solar radiation interaction have no effect on standard bacterial plate count. Both solar radiation ($F = 13.52$; $df = 1, 22$; $P < 0.005$) and distance ($F = 62.59$; $df = 3, 66$; $P < 0.0005$) have significant effects on total coliform; their interaction does not. Coliphage has no effect from solar radiation, but distance ($F = 79.95$; $df = 3, 72$; $P < 0.0005$) and distance-solar radiation interaction ($F = 4.01$; $df = 3, 72$; $P < 0.025$) have an effect; the interaction effect is weak but significant. Solar radiation ($F = 20.01$; $df = 1, 26$; $P < .0005$) and distance ($F = 5.88$; $df = 3, 78$; $P < 0.005$) have significant effects on fecal streptococci, their interaction does not. Mycobacteria has slightly significant effects from solar radiation ($F = 5.31$; $df = 2, 6$; $P < 0.05$) and distance ($F = 3.39$; $df = 3, 18$; $P < 0.05$); the interaction effect approaches significant ($F = 2.50$; $df = 6, 18$; $P = < 0.06$).

For those microorganism groups that show a significant effect for solar radiation, except mycobacteria, calculating the means for each level will indicate whether increased levels of solar radiation reduce microbiological aerosol concentrations. Standard bacterial plate count has, for low levels of solar radiation, a geometric mean of 842.5 (No./m^3) and, for high levels, a geometric mean of 182.5 (No./m^3). Total coliform has geometric means of 1.84 (MFC/m^3) for low levels, and 0.53 (MFC/m^3) for high levels. Fecal streptococci has geometric means of 0.55 (CFU/m^3) for low levels, and 0.13 (CFU/m^3) for high levels. These means indicate concentrations of standard bacterial plate count, total coliform, and fecal streptococci are reduced upon exposure to higher levels of solar radiation. Mycobacteria, although it has a significant effect for solar radiation, was not analyzed because there are three levels of solar radiation and the effect is only slightly significant.

b. *Source and Distance Analysis*

To determine if the spray line is a source and if distance has an effect on microbiological aerosol concentrations, paired comparisons rather than contrasts are used. Because the upwind location in Pre-Fair did not yield typical spray field background levels, only the Post-Fair data were used for the microorganism groups measured in both Pre- and Post-Fair. The microorganisms which were measured only during the Pre-Fair phase were also analyzed.

The preferable statistical technique for making paired comparisons is a t-test for paired samples, as this test is quite powerful in detecting actual differences. However, certain assumptions must be made about the nature of the parent population of the data pairs if this test is to be used. That is, the difference between pairs must have a normal distribution and must be composed of a continuous variable. If these assumptions are violated, more appropriate (although less powerful) tests must be conducted.

The traditional tests for normality (χ^2 goodness of fit, Kolmogorov-Smirnov) are not very useful when dealing with small sample sizes. Thus simple inspection of the data has determined whether or not it conforms to a normal distribution.

In cases where the data are not normal, an attempt to normalize it through an appropriate transformation has been made. The ratio of the standard deviation of a sample to its mean (the coefficient of variation) was used. When this ratio is constant across samples, it indicates that a logarithmic transformation helps to normalize the data.

The t-test assumption of variable continuity must particularly be questioned in those analyses which involve many concentrations of microorganisms or other measurements which are close to, or below, the detection limit. Such data lose the characteristics of a continuous variable and must be analyzed with techniques not requiring this assumption.

In cases where no normalizing transformation can be found or the variable being measured is discontinuous, the first alternative to a t-test is the signed ranks (Wilcoxon) test. This non-parametric test can be safely substituted for the t-test in paired samples when the normality and/or continuity assumptions are violated. Even this test may require a preliminary transformation of the data, as occasionally it is proportional differences which should be considered rather than their absolute values. A logarithmic transformation, in these cases, allows consideration of such differences. In the case of ties between the two members of a pair (leading to a difference score equal to 0), we have deleted such pairs from the data.

For the downwind sample, the arithmetic mean was calculated to obtain a single value for the paired comparisons. If a value is preceded by a less than sign (<), that value was halved; if it is preceded by a greater than sign (>), it was doubled. If an upwind sample is underlined, indicating contamination, that run was deleted from the upwind —50 meter comparison. If all samples at a given downwind distance are underlined, that run was deleted from any comparison involving that distance. If any sample at a given distance is underlined, that sample was deleted in computing the value for that distance.

As mentioned above, either the Wilcoxon signed rank test or t-tests are used. The Wilcoxon is computed as follows. The differences of the paired samples are calculated. The absolute values of the differences are ranked from the smallest value, which is given the value one, to the largest, differences of zero are not included. The signs (+ or —) are restored to the ranks and the ranks are summed for each sign. The test statistic, T, is equal to the smaller of the two sums of ranks. This statistic is evaluated from tables at 0.05 and 0.01, two tailed probability levels. If the number of pairs is greater than or equal to sixteen, then Z, the normal score, can be calculated as:

$$Z = \frac{(\mu - T - 1/2)}{\sigma}$$

where

$$\mu = \frac{n(n + 1)}{4}$$

$$\sigma = \frac{(2n + 1)\mu}{6}$$

T = test statistic
n = number of pairs

This statistic is calculated under the assumption that the frequency distribution of the two groups is the same; therefore, each rank of the differences of pairs is equally likely to have either a positive (+) or negative (—) sign.

The t-test is calculated as:

$$t = \frac{\overline{X}_D}{S_D / N}$$

where

$\overline{X}_D$ = the mean of the differences between the pairs
S_D = the standard deviation of the differences
N = the total number of pairs

In all cases, when a t-test was used, the data has been lognormally transformed.

The results are given in Table G-8. Two comparisons were made, one between the upwind and close downwind samples and one between the close downwind and distant downwind samples. The first comparison determines if the spray line is a source of the microorganism group, the second if there is a decrease in microorganism concentrations with increasing distance. For each comparison, the method used, the test statistic, and conclusions derived are given. If the Wilcoxon signed rank is used and at least sixteen pairs are used in the computation of the statistic, the Z score is given rather than T. A positive test statistic for the upwind-close downwind comparison indicates an increase in microbiological group concentration. A negative test statistic for the close downwind-distant downwind comparison indicates a decrease in microorganism concentration. It can be seen, for all microorganism groups, that there is a significant increase in concentrations from the upwind to the close downwind samples. *Pseudomonas* and standard bacterial plate count (Post-Fair) are borderline significant; the others have highly significant increases. The close downwind-distant downwind comparison has significant decreases for total coliform, coliphage, and fecal streptococci in Post-Fair, and for fecal coliform in Pre-Fair. Standard bacterial plate count shows a decrease; however, it is not significant. Mycobacteria, *Pseudomonas*, and *Clostridium perfringens* show very slight increases. The statistics for these three groups were calculated with nine or less pairs; this small amount of data might be the cause of insignificant results. *Pseudomonas* and *Clostridium perfringens* had, as their distant downwind, samples taken at 100-200 meters from the spray line. This distance may not be sufficient to measure a significant decrease in these microorganism concentrations.

2. Preliminary Assessment of Factors Affecting Microbiological Aerosol Levels

A preliminary assessment was conducted after the Pre-Fair sampling of the factors affecting microbiological aerosol levels on the Pre-Fair aerosol runs. This preliminary assessment was important, both because it justified the form of the microbiological dispersion model equation (3), and because it represents the most comprehensive analysis to date of the effects that atmospheric and operating conditions have on the microorganism-specific parameters I and λ, and thereby on the aerosol concentration.

A simplified form of microbiological dispersion model equation (3) was hypothesized:

$$C = D \times E \times I \times MD \tag{12}$$

where MD = microbiological depletion factors associated with downwind distance or aerosol age

and where C, D, E, and I have their usual microbiological dispersion model definitions. The identity and form of the atmospheric and operating condition factors that are represented by the aerosolization efficiency factor category E, the impact factor category I, and the microbiological depletion factor category MD are considered unknown. Thus, they are unspecified in the model. Instead, the choice of the aerosol factors comprising these categories has been identified independently for each microorganism group by the concentration pattern exhibited by that microorganism in the Pre-Fair aerosol run data.

Taking the natural logarithm of the multiplicative model (12) converts it into an additive format:

$$\ln C = \ln D + \ln E + \ln I + \ln MD \tag{13}$$

Our methodology was to utilize stepwise multiple linear regression to generate the specific ln E, ln I, and ln MD regression variables for the microorganism group from a large list of plausible candidate variables. A separate regression analysis was performed for each quantitative microorganism group. The dependent variable for each microorganism was the natural log of its sampled aerosol concentration, ln C.

The regression data base comprised the available source, meteorological, sampler, and laboratory analysis data for the 20 microbiological aerosol runs and the 5 quality assurance aerosol runs from the Pre-Fair sampling. Each sampler with its associated aerosol run information constituted a separate observation. Each observation was assigned the weight given its microbiological aerosol concentration value, based on the nature of its superscripted footnotes.

Table G-8

SOURCE AND DISTANCE ANALYSIS SUMMARY

	Spray Line a Significant Source? (Upwind vs. 50 m)			Significant Decrease with Distance? (50 m vs. Distant)		
Microbiological Parameter	Method	Statistic	Increase?	Method	Statistic	Decrease?
Standard Plate Count						
Post-Fair	t	t=2.17	Yes, p=0.045	t	t=-0.48	No
Pre + Post Fair	t	t=2.03	Yes, p=0.021	t	t=-0.125	No
Total Coliform						
Post-Fair	Wilcoxon	z=4.3	Yes, p=0.000004	Wilcoxon	z=-4.692	Yes, p=0.000106
Coliphage						
Post-Fair	Wilcoxon	z=4.6	Yes, p=0.000006	Wilcoxon	z=-4.612	Yes, p=0.000006
Fecal Streptococci						
Post-Fair	t Wilcoxon	t=3.43 z=3.49	Yes, p=0.0003 Yes, p=0.0003	t	t=-3.28	Yes, p=0.0004
Mycobacteria						
Post-Fair	Wilcoxon	T=5(n=9)	Yes, p=0.03	t	t=0.98	No
	(Upwind vs. 30-50 m)			(30-50 m vs. 100-200 m)		
	Method	Statistic	Increase?	Method	Statistic	Decrease?
Fecal Coliform						
Pre-Fair	Wilcoxon	T=9(n=14)	Yes, p=0.009	Wilcoxon	T=-0.33(n=9)	Yes, p=0.009
Pseudomonas						
Pre-Fair	Wilcoxon	T=13(n=12)	Yes, p=0.05	Wilcoxon	T=10(n=7)	No
Clostridium perfringens						
Pre-Fair	Wilcoxon	T-0(n=13)	Yes, p=0.001	Wilcoxon	T=19(n=9)	No

Many candidate variables were constructed as potential factors in the aerosolization efficiency, impact and microbiological depletion categories. Guidance in the construction of suitable candidate variables was obtained from the literature, from known biological behavior and physical laws and from our prior analyses of the Phase I data. Sorber, Schaub, and Bausum(92) was particularly helpful in developing meteorological factor relationships. The aerosolization efficiency candidate variables were designed to vary directly with wind velocity, solar radiation and temperature, and inversely with relative humidity. The impact candidate variables were generally in the opposite direction: varying directly with relative humidity and inversely with solar radiation and wind velocity. Separate sets of microbiological depletion candidate variables were developed for downwind distance and aerosol age. The downwind distance set consisted mainly of products of downwind distance and impact-type factors. Similarly, the aerosol age variables were products of aerosol age and impact-type factors.

The diffusion model term D was represented by Turner's line source dispersion model(93). For each microorganism group, some regressions were conducted with the log of this line source dispersion model as a candidate variable. The other regressions were performed utilizing the source, and dispersion aerosol data contain much unexplained variation, which may have been caused by undetected sampler contamination. The low R^2 statistics for fecal streptococci and *Clostridium perfringens* may relate to the frequency with which the sampled aerosol concentrations were near or below the detection limits of these microorganisms.

The aerosol factors tentatively identified for each quantitative microorganism group are also presented in Table G-9. Phrases are used in Table G-9 to describe the identified aerosol factors affecting each microorganism. Each phrase represents a significant regression variable that frequently occurred in the best predictive equations over the three regression cases. The mathematical form of each regression variable referred to by these phrases is listed by factor category in Table G-10.

As an example of the interpretation of Table G-9, consider total coliform. The line model, ln D, is an important regression variable in the best prediction equations for the log total coliform aerosol concentration. Both the source component and the dispersion component of the line model are significant. Temperature is the only common aerosolization efficiency factor in the equations. Low relative humidity measured by the 2 meter tower at the effluent pond appears to have the most pronounced initial aerosol impact effect on the total coliform concentration sampled. However, the lethal impact effect of aerosolization at middle level (near 50 percent) estimated relative humidity just upwind of the sprayer line is also important. Three microbiological depletion factors appeared to explain significant portions of the total coliform aerosol concentration. The most important was the reduction with increasing aerosol age at middle level relative humidity. There was also depletion with age on the high temperature runs, and depletion with downwind distance on the high wind velocity runs.

Before evaluating these factors and developing suitable inferences, it must be emphasized that these are preliminary results. While the regression equations usually had about 100 or more residual degrees of freedom, they actually represent less than twenty distinct sets of meteorological conditions, because several aerosol runs were conducted within a few hours of each other. Furthermore, the Pre-Fair aerosol runs were all obtained in a late spring that was unusually hot and dry. Examination of the meteorological data reveals that some of the important aerosol factor constituents (solar radiation, temperature, and relative humidity away from the ponds and sprayer lines) are highly correlated. This is because the afternoon aerosol runs had high solar radiation, high temperatures, and low distant relative humidities compared to the night runs. The correlation coefficients are 0.68 between solar radiation and temperature, −0.63 between solar radiation and distant relative humidity, and −0.91 between temperature and distant relative humidity. Lacking sufficient design orthogonality among these important meteorological factors, the effects of these factors may be confounded. Thus one meteorological characteristic may incorrectly be identified as an important aerosol

Table G-9
TENTATIVELY IDENTIFIED AEROSOL FACTORS

	Total Coliform	Fecal Coliform
R^2, Coefficient of Multiple Determination	0.79	0.75
Source and Dispersion Category Factors:	Line model (source and dispersion components).	Line model (dispersion component).
Aerosolization Efficiency Category Factors:	Temperature.	Temperature. Relative humidity upwind.
Impact Category Factors:	Low relative humidity at pond. Shock at middle relative humidity.	Low relative humidity at pond. Shock at middle relative humidity. Wind velocity and solar radiation. Wind desiccation. Effluent/air temperature difference.
Microbiological Depletion Category Factors:	Age depletion at middle relative humidity. Temperature with age. Wind velocity with distance.	Temperature with age.

	Standard Plate Count	Coliphage
R^2, Coefficient of Multiple Determination	0.24	0.80
Source and Dispersion Category Factors:	Line dispersion.	Line model (source component).
Aerosolization Efficiency Category Factors:	Solar altitude.	Wind velocity and temperature. Solar altitude.
Impact Category Factors:	Solar radiation.	Low relative humidity at pond. Effluent/air temperature difference. Wind velocity and solar radiation. Low relative humidity upwind. Shock at middle relative humidity.
Microbiological Depletion Category Factors:	Solar radiation with distance.	Downwind distance. Distance depletion at middle relative humidity.

Table G-9 (cont'd)

	Pseudomonas	Fecal Streptococci	*Clostridium perfringens*
R^2, Coefficient of Multiple Determination	0.29	0.44	0.37
Source and Dispersion Category Factors:			Line dispersion.
Aerosolization Efficiency Category Factors.		Temperature.	Relative humidity upwind. Wind velocity.
Impact Category Factors:	Wind desiccation.	Wind desiccation.	Wind desiccation. Shock at middle relative humidity. Wind and temperature.
Microbiological Depletion Category Factors:	Temperature with distance.	Distance depletion at middle relative humidity.	Age desiccation.

Table G-10
EXPLANATION OF AEROSOL FACTOR PHRASES

Category	Aerosol Factor Phrase	Regression Variable Formula
Source and Dispersion		
	Line model.	$\ln D$
	Line source.	$\ln\left(\frac{2q}{\sqrt{2\pi}\,u\cos\phi}\right)$
	Line dispersion.	$\ln\left[\left(\frac{1}{\sigma_z}\right)\exp\left(-\frac{1}{2}\left(\frac{Z-H}{\sigma_z}\right)^2\right)\right]$
Aerosolization Efficiency		
	Relative humidity upwind.	Adjusted Livermore relative humidity ERHS = estimated relative humidity upwind of source
	Solar altitude.	SA = sin (solar altitude)
	Temperature.	T, °C
	Wind velocity.	U, m/sec
	Wind velocity and temperature.	U x T
Impact		
	Effluent/air temperature difference.	$(T-25)^2$
	Low relative humidity at pond.	2m tower relative humidity
	Low relative humidity upwind.	ERHS
	Shock at middle relative humidity.	RH50SQ = $(\text{ERHS} - 0.5)^2$
	Solar radiation.	SACC = SA x (1 - cloud cover)
	Wind desiccation	U/ERHS
	Wind velocity and solar radiation.	U x SACC
Microbiological Depletion		
	Aerosol age.	AA = DD/U
	Age desiccation	AA/ERHS
	Age depletion at middle relative humidity.	$\text{AA}/(\text{RH50SQ} + 0.01)^2$
	Distance depletion at middle relative humidity.	$\text{DD}/(\text{RH50SQ} + 0.01)^2$
	Downwind distance.	DD = $(w + d)/\cos\phi$
	Solar radiation with distance.	DD x SACC^2
	Temperature with age.	AA x T
	Temperature with distance.	DD x T
	Wind velocity with distance.	DD x U

level factor, when in fact it is simply highly correlated with the actual causative factor. The identification of microbiological depletion factors is also hampered by the limited sampler distance range utilized in Pre-Fair. The microbiological depletion occurring within 100 meters of the wet-line edge was generally less than one order of magnitude.

To compensate for these design deficiencies, the tentatively identified aerosol factors should be evaluated conservatively. Our approach is to require the confirmation of several related microorganism groups to make our preliminary inferences.

Examination of Table G-9 shows that similar factors affect the total coliform, fecal coliform, and coliphage levels within each of the four factor categories. The diffusion model D is identified as important for all three groups. Temperature is indicated to have an important effect on wastewater aerosolization efficiency in all three groups' regressions. Low pond relative humidity and middle upwind relative humidity both have lethal impact effects on all three indicator microorganism groups. Decay at middle relative humidities and at high temperature is suggested as the reason for microbiological depletion.

Table G-9 provides some evidence that the three pathogenic bacteria, *Pseudomonas*, fecal streptococci, and *Clostridium perfringens*, may also be affected by similar environmental variables. All appear to be initially reduced in viability by strong, dry winds. Desiccation also appears to play a role in their depletion with aerosol age or distance.

For each of the microorganism groups (total coliform, fecal coliform, and coliphage) whose aerosol concentrations were amenable to modeling, the diffusion model D was an important factor. Furthermore, separate aerosolization efficiency, impact, and viability decay factors were identified as affecting the aerosol concentration emanating from the spray line. This evidence from the Pre-Fair sampling supports the equation (3) form used to express the microbiological dispersion model. It also suggests how meteorological conditions may affect the model parameters I and λ for different microorganism groups.

APPENDIX H
DATA USED IN THE EVALUATION OF THE MICROBIOLOGICAL DISPERSION MODEL

APPENDIX H
LIST OF TABLES

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H-6 MODEL EVALUATION DATA FOR PSEUDOMONAS, CLOSTRIDIUM PERFRINGENS, AND MICROBACTERIA AT PLEASANTON 474

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Table H-1
MODEL EVALUATION DATA FOR STANDARD PLATE COUNT

AEROSOL RUN NUMBER	TEMPERATURE °C	RELATIVE HUMIDITY %	SOLAR RADIATION W/M²	WIND VELOCITY, M/S	σ_z DISTRIBUTION PERCENTILE	SAMPLER DISTANCE, m	AEROSOL CONCENTRATIONS MEASURED C-0	PREDICTED P	ORD LOG (C/P)
PLEASANTON							(CFU/m³)		
M1-16-19	10	74	0	1.6	60	25	2530	300	0.92
M1-20-23	18	40	390	2.0	40	30	1320	620	0.33
M1-24-25	11	70	0	1.1	60	25	1160	2000	-0.24
M1-26	11	64	0	2.2	60	20	860	930	-0.34
M1-27-30	28	9	460	5.1	25	40	2120	280	0.87
M2-4	9	69	370	2.0	40	50	630	510	0.09
M2-18	12	53	0	2.3	60	50	670	3600	-0.74
DEER CREEK LAKE							(CFU/m³)		
1	27	56	790	3.8	25	21 41 200	480 430 46	510 370 42	-0.02 0.06 0.04
2	31	53	750	3.9	25	21 41 200	360 460 150	160 114 11	0.35 0.61 1.15
3	31	60	790	3.9	25	21 41 200	390 440 46	320 230 31	0.08 0.28 0.18
4	32	63	410	3.6	60	21 41	260 109	220 123	0.08 -0.05
7	26	53	600	4.8	40	30 50 50, el.	1230 1160 330	280 220 170	0.64 0.72 0.28
8	27	67	120	4.6	40	30 50 50, el.	390 390 111	330 270 200	0.06 0.16 -0.25
10	26	73	620	5.6	40	30 50 50, el.	850 760 160	360 280 240	0.37 0.44 -0.18
11	27	63	600	3.0	40	30 50 50, el.	240 230 90	78 59 50	0.49 0.59 0.26
12	28	59	760	3.1	25	30 50 50, el.	160 190 93	48 29 28	0.51 0.82 0.52
13	28	60	560	3.9	40	30 50 50, el.	150 160 42	73 52 44	0.31 0.50 -0.02

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AEROSOL RUN NUMBER	TEMPERATURE °C	RELATIVE HUMIDITY %	SOLAR RADIATION W/m^2	WIND VELOCITY m/s	I, DISTRIBUTION PERCENTILE	SAMPLER DISTANCE m	AEROSOL CONCENTRATIONS		GMD LOG (C-B)/P
							MEASURED C-B	PREDICTED P	
14	22	82	115	3.4	50	30	170	160	0.04
						50	140	111	0.10
						50, el.	58	77	-0.12
15	25	65	700	4.0	25	30	104	180	-0.25
						50	56	140	-0.39
16	27	72	600	3.8	40	30	890	130	0.84
						50	760	101	0.88
						200	170	28	0.78
17	28	44	600	5.3	40	30	560	130	0.62
						50	400	104	0.58
19	22	70	0	1.1	60	30	400	120	0.51
						50	330	97	0.53
						200	200	29	0.84
20	24	45	720	3.0	25	30	340	96	0.54
						50	400	66	0.78
21	25	55	690	2.4	25	30	340	86	0.59
						50	125	51	0.39
22	26	62	670	3.6	25	30	1200	115	1.02
						50	990	85	1.06
						200	140	14	1.02
24	29	50	560	3.9	40	30	440	740	-0.23
						50	310	580	-0.25
						200	52	160	-0.50
25	28	48	230	2.9	50	30	300	470	-0.20
						50	160	400	-0.40
FORT HUACHUCA							(CFU/m^3)		
74-1	18	68	470	4.1	40	46	1210	1630	-0.13
						61	330	1240	-0.57
						152	81	310	-0.73
74-2	19	60	460	4.9	40	46	510	700	-0.14
						91	200	430	-0.33
						152	98	170	-0.23
74-7	24	32	430	3.8	40	46	1080	990	0.04
						61	500	710	-0.15
74-8	18	70	580	6.4	40	61	320	32	1.00
74-9	19	58	750	6.5	25	49	70	380	-0.74
						107	34	108	-0.50
						152	57	55	0.01
74-10	23	49	590	6.0	40	49	180	640	-0.56
						107	210	220	-0.01
						198	130	33	0.59
74-11	11	62	730	2.1	25	46	690	112	0.79
						91	92	19	0.68
74-12	13	56	540	2.2	40	46	700	290	0.38
						69	160	100	0.20
75-2	24	19	580	4.0	40	46	870	645	0.13
						92	18	2.9	0.80
75-3	23	20	105	2.2	50	46	1420	970	0.17
75-4	20	27	490	4.3	40	46	150	125	0.08
						76	62	68	-0.04
75-9	23	5	0	1.9	60	46	10000	3000	0.55
						76	4000	1270	0.50
						152	260	166	0.20
75-10	21	6	0	2.0	60	46	4100	430	0.99
						61	1730	350	0.69
75-12	22	26	770	3.1	25	46	220	140	0.18
						76	900	53	1.23
						101	146	29	0.70
75-13	27	13	650	5.0	25	46	1210	1370	-0.05
						76	2720	700	0.59
						101	970	430	0.36
75-14	24	20	240	3.5	50	76	720	320	0.36
						101	330	200	0.20

AEROSOL RUN NUMBER	TEMPERATURE °C	RELATIVE HUMIDITY %	SOLAR RADIATION W/M²	WIND VELOCITY M/S	I, DISTRIBUTION PERCENTILE	SAMPLER DISTANCE m	AEROSOL CONCENTRATIONS MEASURED C-B	AEROSOL CONCENTRATIONS PREDICTED P	OMD LOG (C-B)/P
PLEASANTON - confirmed							(MFC/M²)		
M1-16-19	10	74	0	1.6	60	25	8.5	4.2	0.31
M1-20-23	18	40	390	2.0	40	30	1.9	0.47	0.61
M1-24-25	11	70	0	1.1	60	25	14.4	20.0	-0.14
M1-26	11	64	0	2.2	60	20	9.9	13.9	-0.15
M1-27-30	28	9	660	5.1	25	40	0.33	1.26	-0.58
M2-18	12	53	0	2.5	60	50	9.9	7.0	0.15
M2-29	22	29	680	3.5	25	50	0.09	1.35	-1.18
M2-34	16	25	0	1.9	60	50	6.2	8.3	-0.13
DEER CREEK LAKE - Presumptive on Endo Broth							(MFC/m3)		
14	22	82	115	3.4	50	30 50	5.6 10.4	0.50 0.31	1.05 1.53
15	25	65	700	4.0	25	30 50	2.3 8.5	0.23 0.12	1.00 1.85
16	23	72	600	3.8	40	30 50	9.1 1.95	0.17 0.11	1.73 1.27
22	26	62	670	3.6	25	30 50	1.7 3.4	0.057 0.028	1.48 2.09
FORT HUACHUCA - Presumptive on Endo Agar							(CFU/m3)		
74-1	18	68	670	4.1	40	46 152	146 8.8	530 36.9	-0.56 -0.62
74-2	19	60	640	4.9	40	46 91 152	140 45 54	42 17 2.9	0.53 0.42 1.27
74-7	24	32	630	3.8	40	61 152	57 17.7	123 11.1	-0.34 0.20
74-8	18	70	580	6.4	40	61 152	246 264	6.8 1.1	1.56 2.37
74-9	19	58	750	6.5	25	49 107	12.0 7.0	3.4 0.53	0.55 1.12
74-10	23	69	590	6.0	40	49 107 198	34 11.0 1.5	40 8.9 0.71	-0.07 0.09 0.33
74-11	11	62	730	2.1	25	46 91	208 19	10.5 0.39	1.30 1.69

Table H-3
MODEL EVALUATION DATA FOR TOTAL COLIFORM

AEROSOL RUN NUMBER	TEMPERATURE °C	RELATIVE HUMIDITY %	SOLAR RADIATION W/M ~	WIND VELOCITY M/S	I, DISTRIBUTION PERCENTILE	SAMPLER DISTANCE m	AEROSOL CONCENTRATIONS		OMD LOG $\left(\frac{C-B}{P}\right)$
							MEASURED C-B	PREDICTED P	
74-12	13	56	540	2.2	40	46 69	284 45	53 11.1	0.73 0.61
75-2	24	19	580	4.0	40	46	20	7.8	0.40
75-12	22	26	770	3.1	25	46 101	8.0 4.0	5.1 0.28	0.19 1.16
75-14	24	20	240	3.5	50	46 76 101	30 100 30	95 39 21	-0.50 0.41 0.16
FORT HUACHUCA - Presumptive on Endo Broth							(MFC/m^3)		
74-1	18	68	470	4.1	40	152	0.75	0.27	0.44
74-7	24	32	430	3.8	40	61	36	11.4	0.50
74-9	19	58	750	6.5	25	107	0.60	0.41	0.17
75-2	24	19	580	4.0	40	46	3.3	0.12	1.43
75-12	22	26	770	3.1	25	76 101	0.40 1.6	0.29 0.08	0.14 1.28
75-14	24	20	240	3.5	50	76 101	4.7 9.0	20 10.8	-0.64 -0.08

Table H-3
MODEL EVALUATION DATA FOR FECAL COLIFORM

AEROSOL RUN NUMBER	TEMPERATURE °C	RELATIVE HUMIDITY %	SOLAR RADIATION W/M^2	WIND VELOCITY M/S	I, DISTRIBUTION PERCENTILE	SAMPLER DISTANCE m	AEROSOL CONCENTRATIONS MEASURED C-B	AEROSOL CONCENTRATIONS PREDICTED P	OMD $LOG_{10}\left(\frac{C-B}{P}\right)$
PLEASANTON							(MFC/m^3)		
M1-8	23	32	840	2.5	25	5	0.80	0.62	0.11
M1-16-19	10	74	0	1.6	60	25	1.7	0.53	0.51
M1-20-23	18	40	390	2.0	40	30	0.31	0.04	0.88
M1-24-25	11	70	0	1.1	60	25	4.0	2.5	0.21
M1-26	11	64	0	2.2	60	20	1.7	0.96	0.25
FORT HUACHUCA							(MFC/m^3)		
75-12	22	26	770	3.1	25	76	0.30	0.003	1.97
75-14	24	20	240	3.5	50	101	1.20	0.43	0.44

Table H-4
MODEL EVALUATION DATAFOR COLIPHAGE

AEROSOL RUN NUMBER	TEMPERATURE °C	RELATIVE HUMIDITY %	SOLAR RADIATION W/M^2	WIND VELOCITY m/s	I, λ DISTRIBUTION PERCENTILE	SAMPLER DISTANCE m	AEROSOL CONCENTRATIONS MEASURED C-B	AEROSOL CONCENTRATIONS PREDICTED P	OMD LOG $\left(\frac{C-B}{P}\right)$
Pleasanton							(PFU/m^3)		
M1-24-25	11	70	0	1.1	60	25	2.8	5.6	-0.30
M1-26	11	64	0	2.2	60	25	1.5	2.9	-0.28
M2-8-9	17	58	0	1.7	60	50	1.01	2.4	-0.37
M2-26	17	39	700	4.7	25	50	0.12	0.40	-0.52
M2-27-28	23	25	480	3.1	40	50	0.49	1.38	-0.45
Fort Huachuca							(PFU/m^3)		
75-3	23	20	105	2.2	50	46	5300	1040	0.71
						76	9600	1710	0.75
75-4	20	27	490	4.3	40	46	940	1500	-0.20
						76	430	480	-0.05
						152	40	156	-0.59
75-9	23	5	0	1.9	60	46	5800	16500	-0.45
						76	7500	7500	-0.00
75-10	21	6	0	2.0	60	46	7500	4400	0.23
						61	5600	2400	0.27
75-13	27	13	650	5.0	25	46	1180	360	0.52
						76	410	112	0.56
						101	690	79	0.94
75-15	26	22	750	4.7	40	46	510	180	0.47
						76	160	58	0.43
						101	450	47	0.98

Table H-5

MODEL EVALUATION DATA FOR FECAL STREPTOCOCCI

AEROSOL RUN NUMBER	TEMPER-ATURE °C	RELATIVE HUMIDITY %	SOLAR RADIATION W/m^2	WIND VELOCITY m/s	I, λ DISTRIBUTION PERCENTILE	SAMPLER DISTANCE m	AEROSOL CONCENTRATIONS MEASURED C-B	AEROSOL CONCENTRATIONS PREDICTED P	OMD $\log_{10}\left(\frac{C-B}{P}\right)$
Pleasanton							(CFU/m^3)		
M1-24-25	11	70	0	1.1	60	25	1.6	2.9	-0.26
M1-26	11	64	0	2.2	60	20	0.17	3.6	-1.33
M2-8-9	17	58	0	1.7	80	50	0.68	3.6	-0.73
M2-22	15	33	840	5.6	25	50	0.17	0.36	-0.33
M2-27-28	23	25	480	3.1	40	50	0.30	1.66	-0.74
M2-29	22	29	680	3.5	25	100	0.15	0.25	-0.23
M2-32	13	37	0	2.2	60	50	0.19	0.92	-0.69
M2-36	24	15	450	4.1	40	50	0.13	0.60	-0.66
Fort Huachuca							(MFC/m^3)		
75-12	22	26	770	3.1	25	76 101	0.20 0.50	0.044 0.026	0.65 1.28

Table H-6
MODEL EVALUATION DATA FOR PSEUDOMONAS, CLOSTRIDIUM PERFRINGENS, AND MICROBACTERIA AT PLEASANTON

AEROSOL RUN NUMBER	TEMPERATURE °C	RELATIVE HUMIDITY %	SOLAR RADIATION W/m^2	WIND VELOCITY m/s	I, λ DISTRIBUTION PERCENTILE	SAMPLER DISTANCE m	AEROSOL CONCENTRATIONS MEASURED C-B	AEROSOL CONCENTRATIONS PREDICTED P	OMD $\log_{10}\left(\frac{C-B}{P}\right)$
							(CFU/m^3)		
Pseudomonas									
M1-24-25	11	70	0	1.1	60	25	77	790	-1.01
M-26	11	64	0	2.2	60	20	146	430	-0.47
M1-32	37	6	900	3.8	25	10	3.0	24	-0.90
M1-33	34	20	670	5.6	25	20	3.5	18	-0.71
							(MPN/m^3)		
Clostridium perfringens									
M1-7	10	60	0	4.2	60	5	1.10	2.2	-0.30
M1-24-25	11	70	0	1.1	60	25	0.32	8.9	-1.45
							(CFU/m^3)		
Mycobacteria									
M2-15	9	52	560	4.7	75	50	10.8	2.3	0.66
M2-27-28	23	25	480	3.1	40	50	0.42	0.50	-0.08
M2-33	22	16	430	7.2	40	50	1.55	1.19	0.11
M2-38	19	23	290	3.4	75	50	10.8	1.05	1.01

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